A STUDY OF THE EFFECT OF REORGANISING THE PRESCRIBED CURRICULAR FRAMEWORK ON THE COMBINATORIAL REASONING AND CONTROLLING OF VARIABLES ON GRADE IX STUDENTS

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PREFACE

Man distinguishes himself from other creatures by his abstract reasoning capacity and his ability to communicate his knowledge by highly complex symbolic processes. There are few scientists who have explored the universe of cognition, and contributed to the understanding of the realm of knowledge, with greater genius, care, and scientific intution than Jean Piaget.

This report is on a study attempting at inducing the development of logical operations, based on the Piagetian theoretical framework, through a 'guided discovery' based model of instruction in an actual Indian urban classroom condition, taking into consideration all its constraints. There is no study conducted in Indian conditions to derive implications for the experiment mentioned above. This makes it necessary to make the report comprehensive and self sufficient. Therefore, the Piagetian theoretical framework is briefly described and the question of inducing cognitive development is discussed. What follows is an empirical support to this hypothesis. Studies on acceleration of cognitive structures conducted under different field conditions are reviewed tracing a trend and deriving implications for a model of instruction which might induce cognitive development of learners. Following this the field conditions in India is presented and a model of instruction suitable to these conditions to induce cognitive development is detailed. Subsequently the procedural details of finding an answer to the research question is described.

CHAPTER I

THEORETICAL FRAMEWORK

1.0 Evolution of Scientific Knowledge

Throught history men have observed various phenomena of nature and then attempted to explain them. Man's knowledge of such phenomena, observed and explained at different points of time, has gone through a number of stages (Robinson, 1968, p.15). At a given stage the knowledge of the various phenomena and their interrelationships exists in the form of a well connected structure. This structure is internally consistent in that it accounts for almost all observations made during that time. If any contradictory obsrvation is made during this time, it is either rejected as invalid or modified to fit into the structure. When many such observations are made and the existing structure fails to explain or account for these observations, there is created a disequilibrium and thus arises a need for the structure to undergo modifications in order to accommodate the new observations. Therefore, such an observation or a set of observations may trigger several changes in the knowledge structure thereby evolving into a new stage in the evolution of human knowledge. This is what Kuhn (1962) calls as normal and revolutionary phases of science. The new stage is relatively stabler in that it can assimilate many more observations than the previous stage.

So, the structure of knowledge is not to be taken as a static one, instead it is dynamic, and the evolution may be seen in terms of its change from a less stable equilibrium to that of a stabler one through an active interaction of the human mind with the environment[1]. This stage wise development of the knowledge structure may be further explained using a couple of illustrations from the history of science. During the period of Ptolemy (c. 140 A.D.) and for another 1300 years, it was believed that the celestial objects revolved round the earth in uniform motion. There was difficulty when some observations regarding the motion of planets conflicted with the existing knowledge structure. The structure was extended and not modified in an effort to assimilate the contradictory observations. When many such observations could not fit into this structure of knowledge, the then philosophers claimed that the observations must be wrong (Koestler, 1959, p.69). The sixteenth century Polish astronomer Copernicus set up a milestone in restructuring the understanding of the universe. His view of the universe (that the sun, not the earth, is at the centre of the system) could accommodate those unaccounted observations and also many more which were made later by others (Feldman and Ford, 1979, p.20). Thus, the structure of knowledge evolved from a lower stage to a higher one which could accommodate the previous observations as well as observations made during that period. Another major structural change that took place in the human understanding of his

environment is the development of quantum mechanics which led to the breakdown of the Newtonian mechanics. The work of Heisenberg, Dirac, Einstein, etc., forced the scientists to give up the classical explanations (Robinson, 1968,p.18).

Such a step wise evolution is also true in the case of the development of concepts which form part of the total knowledge structure. For example, the concept of the unit of matter and its constitution has undergone several such stages of evolution in history. The discovery of the fundamental particle 'electron' by J.J. Thomson in the year 1897 made a major change in the understanding of the unit of matter i.e., atom. It was then believed that positive and negative partic'' are embedded in a hard sphere called the atom. This concept of the atom could explain several observations regarding the constitution of matter and its transformations. But, when Rutherford in 1909 bombarded a collection of atoms with positive particles, they passed through. The then existing concept of the atom failed to explain this observation. There arouse a need for the conceptual structure to undergo transformation to accommodate the new observation. This led to the discovery of the Rutherford model of the atom with a heavy nucleus at the centre and the electrons moving around i-

The above examples are a few among the umpteen examples which show the stage wise evolution of concepts as well as the total knowledge structure through a process of

assimilation-accommodation-equilibration. This process is further elaborated in the coming sections.

1.1 An Individual's Understanding of his Environment

An individual, right from his childhood, interacts with his environment and adapts cognitively. He progressively constructs his cognitive structure through active interaction with his surroundings[2]. This includes elementary sensorymotor actions of a child to the most sophisticated intellectual operations of an adult. Such a construction of reality by an individual does not seem to proceed in a gradual and continuous fashion; rather it evolves in a stagewise fashion. An early example of such an evolution is the construction of the notion of the permanence of objects by a child by about the age of 9-12 months[3]. During the first few months of existence, the child is not aware of permanent objects, but only of pictures which appear, dissolve and then reappear. At this stage the child believes that objects depend on his action of looking for them. For the object to become permanent the child has to construct a new structure. This he does when the child discovers from repeated failures to recover an object from the initial position and later by successfully following it around an obstacle. At this point the child's body instead of being considered the centre of the world becomes an object like any other. Piaget (1976,p.14), describes it as a 'Copernican revolution', babies accomplish in

twelve to eighteen months. Such a stagewise evolution in an individual's construction of cognitive structures can be seen in his understanding of the environment[4].

1.2.0 Piaget's Theory

Piaget's theory of development, which is particularly concerned with the development of cognitive functions, is impossible to understand if one does not begin by analysing in detail the biological presuppositions from which it stems and the epistemological consequences in which it ends. Piaget (1976) says that he finds the same problems and same types of explanation to three processes viz., 1) the adaptation of an organism during its growth, 2) the adaptation of intelligence in the course of the construction of its own structures, and 3) the establishment of cognitive structures progressively constructed by continuous interaction between the subject and the external world. In the common view, the external world is entirely separate from the subject and an objective knowledge then appears to be simply the result of a set of perceptive recordings, motor associations, verbal descriptions and the like. But this passive interpretation of the act of knowledge is in fact contradicted at all levels of development. Actually, inorder 'to know' objects, the subject must act upon them, and therefore transform them; he must displace, connect, combine, take apart, and reassemble them. From the most elementary sensorimotor actions to the most sophisticated intellectual

operations, which are interiorised actions carried out mentally, knowledge is constantly linked with actions or operations, that is, with transformations (Piaget, 1976,p.12). The result of these transformations is the progressive construction of knowledge structures. But these structures are the result of construction and are not given in the objects, since they are dependant on action, nor in the subject, since the subject must learn how to coordinate his actions. The origin of knowledge lies in an inextricable interaction between both subject and object, such that what is given physically is integrated in a logicomathematical structure involving the coordination of the subject's actions (Piaget, 1976,p.16).

The above discussion on construction of structures seem to overemphasise the importance of experience. This is not true. According to Piaget the genesis of the mechanism of knowledge cannot be explained by any of the classical factors of developmental theory; it is not solely due to maturation, it does not result solely from learning on the basis of experience, and it does not result solely from social transmission. Piaget advances the hypothesis that another factor must be identified alongwith those of the above. This is the factor of equilibration (Inhelder, 1970; Thomas, 1977)*.

1.2.1 Equilibration

Piaget postulates that each organism is an open, active,

self-regulating system. Mental development would be then characterised by progressive changes in the process of active adaptation. Elkind (1967) paraphrases that 'at each level of development there are two poles of activity: change in the structure of the organism in response to environmental intrusions (accommodation) and changes in the intruding stimuli due to the existing structure (assimilation). Any action on the part of a subject gives rise to 'schemes' of assimilation[5]. That is, an object can be taken into certain schemes through the actions that are carried out on it; each of those schemes of assimilation goes hand in hand and with an aspect of accommodation of the schemes to the situation. Thus, when a subject takes cognisance of or relates to an object, there is a pair of processes going on. It is not just straight association. There is a bipolarity, in which the subject is assimilating the object into his schemes and at the same time accommodating his schemes to the special characteristic of the object. And in this bipolarity and sharing of processes, there is already a factor of equilibration between assimilation and accommodation. Piaget (1977,p.11), speaks of three kinds of equilibrium. The first one is in the relationship between assimilation and accommodation, discussed above. The second kind of equilibrium is an equilibrium among the subsystems of the subject's schemes. In reality, the schemes of assimilation are coordinated into partial systems,

referred to as subsystems in relation to the totality of the subject's knowledge. These subsystems can present conflicts among themselves and as they evolve, there is a constant need for coordination of the two, that is, an equilibration of subsystems. The third kind of equilibrium in cognitive development appears to be fundamental. Little by little, there has to be a constant equilibrium established between the parts of the subject's knowledge and the totality of his knowledge at any given moment. Pascual-Leone and Goodman (1979, p.304) explicate the notion of equilibration as follows: 'it is an active disposition of the psychological organism to spontaneously undergo reconstructions or structural changes in order to (a) maximise the internal consistency among its functional parts, (b) maximise adaptation in its dealings with the environment, and (c) minimise internal complexity in its organisation.

1.2.2 Stages in cognitive development.

The intellectual development model of Piaget has suggested four major stages. First is a sensorymotor stage which extends from birth to about two years and which occurs before the advent of language. This period is characterised by what Piaget(1971) calls 'sensorimotor intelligence', which is a type of intelligence resulting in a certain number of performances, such as the organisation of spatial relationships,

the organisation of objects and a notion of their permanence, the organisation of causal relationships, etc. After the sensorimotor period around the age of two years, comes another period which starts with the symbolic function. This is called the 'preoperational stage' since the child is capable of having representational thought by means of the symbolic function. The third period starts at around the age of seven or eight years and is characterised by the inception of operations. The term operation is obviously quite important on this intellectual development model. As Piaget (1964a, p.17) has stated 'to know an object is to act on it'. Eventually a child reaches a point where he learns from the actions rather than just from the objects. When learners discover the properties of their actions, they have begun to perform mental operations. An operation obviously is reversible and is an interiorised action (discussed in detail in the next section). Piaget describes the third stage i.e., 'concrete operational' stage as follows: 'the first operations appear, but I call this concrete operations because they operate on objects and not yet on verbally expressed hypotheses'. He describes the concrete operational thinker thus: 'in order to think children in the concrete stage need to have objects in front of them that are easy to handle or else be able to visualise objects that have been handled and that are easily imagined without any real effort'. In the last stage of the Piagetian model, formal operational thought, individuals

think with verbally expressed hypotheses. A learner who has acquired formal operational thought will be able to visualise Newton's second law of motion, relate the law of supply and demand to the movements of the stock exchange, appreciate the symbolism in a poem, succeed in Euclidean geometry, and construct the model of the atom from available data. This type of thought is 'the stock in trade of the logistitian, the scientist or the abstract thinker' says Bruner (1977,p.37).

1.2.3 Mental operations.

According to Piaget (Piaget, 1950; 1954a; 1954b; 1955; 1957) and Inhelder (Piaget and Inhelder,1956; Inhelder and Piaget, 1958) actions performed by the subject constitute the substance or raw material of all intellectual and perceptual adaptation. In infancy, the actions in question are relatively overt, sensorimotor ones. With development, intelligent actions become progressively internalised and covert (Flavell, 1963, p.182). As internalisation proceeds, cognitive actions become more and more schematic and abstract, broader in range, more, what Piaget calls reversible, and organised into systems which are structurally isomorphic to logico-mathematical systems[6]. Thus the overt, slow paced actions of the neonate eventually get transformed into lightning-quick, highly organised systems of internal operations. However, despite the enormous differences between simple sensorimotor adjustments

and the abstract operations which characterise mature, logical thought, the latter are as truly actions as are the former.

During the first few weeks of life the child depends largely on reflexes, the most important of which is the sucking reflex. Experience in using the sucking reflex causes modifications of this inherited schema so that it becomes more sophisticated[7]. After the first few weeks, the infant develops behaviour patterns that go beyond the primary reflex actions. Motor coordination develops that allows the child to place objects in the mouth and the first signs of curiosity in surrounding objects are observed. During the second year of life, the child searches for new things merely for the sake of finding out about new situations. Nearer the end of second year the child begins to show evidence that it can mentally represent objects that are no longer present. This symbolic function signals the beginning of representational thought. The thought is still very egocentric and 'other' points of view are not within the child's frame of reference. The child during this stage is unable to reverse the order of events in thought and arrive once again at the beginning point. This feature of thinking from two to seven years of age is perhaps emphasised most by Piaget as the major obstacle to real operational thinking (Good,1977 p.152). The first operations appear at the concrete operational stage (refer section 1.2.1). Piaget has divided operations during the concrete operational

period into two main groups: logical and infra-logical. The logical operations such as establishing one to one correspondence, adding and subtracting are not tied to any specific quantities, space, time, or the like as are the infra-logical operations (Good, 1977, p.153). Concrete operations require objects that can be grouped or ordered. The concrete groupings involve reversibility by either inversion or reciprocity but not by a synthesis of the two as in the 'formal' operations. The groupings are only simple or multiple classifications rather than a complete combinatorial system. When the adolescent accomplishes a complete combinatorial system, problems of a concrete as well as an abstract nature can be solved. Propositional thought is characterised by a complete combinatorial system that allows for separation and control of variables and a generalised hypothetico-deductive approach to solving problems. For a concrete operational thinker propositional thought is limited by an incomplete combinatorial system. Inhelder and Piaget (1958) have noted that one to one class multiplication is involved in such an approach and the subject discovers the combinations in a concrete manner. Sometimes, the twelve year old child will also include two by two class multiplication, but all combinations are not exhausted. Propositional thought presupposes the ability to make all possible combinations even though it may not be possible to actually verify each one experimentally (Good, 1977 p.132).

Piaget does not have arithmatical operations in mind so much as logical operations, of which the most common example are such things as conjunction, disjunction, implications and the like (Halford, 1978 p.12). The conjunction of two things, A and B, is anything which includes A and B, and is written as A·B. Thus the conjunction of things which are 'red' and 'triangular' is all the things which are red triangles. The disjunction of A and B (AvB) is all the things which are either A or B. Thus the disjunction of red and triangle is all triangles, all red things, and all things which are both red and triangular. The implication, A implies B (A⊃B), means that whenever A occurs B occurs also. Halford (1978 p.12) says that logical operations of this kind is a particular set of contingencies between events, which can be summarised in a form which is called a truth table. Below given is such a 'truth table' for conjunction (A·B), disjunction (AvB), and implication (A⊃B).

Table 1.1

Truth table for conjunction, disjunction, and implication.

A	B	Conjunction A·B	Disjunction AvB	Implication A⊃B
1	1	1	1	1
1	0	0	1	0
0	1	0	1	1
0	0	0	0	1

On the left are shown the two variables, A and B. They are variables because they have two possible values, present or absent (corresponding to true or false). Presence of a variable is signified by 1, absence by 0. All the four combinations of presence and absence of A and B are shown. The next column shows whether each combination of values of A and B is consistent with the concept of conjunction. For instance, the first row shows that when A and B are both present, A and B (A·B) is true, as also are AvB and A⊃B. In the second row, when A is present but B is not, then A·B is not true, but A or B (AvB) is true. In the same case, A B is not true, because if A is present but not B, then it cannot be true that A implies B. Consider now the last row, when A and B are both absent, both conjunction and disjunction are false, but implication is true because this case is consistent with the proposition that A implies B. Each concept in the truth table is a binary operation in that values of two variables are mapped into a value of another variable. Thus table 1.1 defines three distinct operations (Halford, 1978 p.13). Actually sixteen such operations can be defined by taking all possible assignments of this kind; these are the sixteen binary operations of propositional logic, which Piaget makes the basic building blocks of formal operations. The above discussion on the concrete operational thought (four binary operations), and the formal operational thought (sixteen binary operations), can be

brought out clearly with a couple of illustrations. Hunt (1961) describes the limitations of the concrete phase in dealing with these operations with the following example. He assumes that the propositions concern the class of animals which are divided into invertibrates (I) and vertibrates (V). The class of animals is also divided into those which live on land and are terrestrial (T) and those which live in water and are aquatic (A). If a child in the concrete operational stage is given the task of describing the population of animals on a newly discovered planet, he would be limited to the empirical task of searching for animals and assessing them to the four classes based on a two-way classification with the following entries in the 2x2 contingency table:

VT	VA
IT	IA

But if an adolescent or adult in the stage of formal operations were given the same task he would be capable, theoretically, of generating all the various combinations of classes of animals which were possible, and would be able to set out these possibilities without the benefit of empirical support as given in table 1.2 (Seggie, 1978 pp.350-351).

Table 1.2

Possible combinations of classes of animals.

1.	No animals at all
2.	Only VA
3.	Only VT
4.	Only IA
5.	Only IT
6.	VA and VT but no IA or IT
7.	VA and IA but no VT or IT
8.	VT and IT but no VA or IA
9.	IA and IT but no VA or VT
10.	VA and IT but no VT or IA
11.	VT and IA but no VA or IT
12.	VA, VT, and IA but no IT
13.	VA, VT, and IT but no IA
14.	VA, IA, and IT but no VT
15.	VT, IA, and IT but no VA
16.	All four classes

The sixteen binary operations, detailed in the above table, is constructed by taking each of the binary operations, shown in table 1.1, and negating or inverting it, or by performing other transformations on it. These are operations on the four binary operations. One such transformation is called identity or null transformation (I) which preserves the original operation. The next possible transformation is called the inverse (N), which negates each operation; e.g., it turns A and B into not A or not B. The reciprocal transformation (R) reverses the operation in a different way, by inverting the individual terms, so that R (A•B) becomes $\bar{A}\cdot\bar{B}$. The fourth transformation is actually the inverse of the reciprocal, and converts A•B into A∨B, etc. Actually there is a simple rule for each transformation: for the inverse, replace

all the 1s in the truth table with 0s, and vice versa; the pattern of 1s and 0s for the reciprocal is a mirror image of the pattern for the original operation, and the correlate can be found by simply taking the inverse of the reciprocal. These rules hold for all the sixteen binary operation given in table 1.2. This group of transformations on logical operations is what Piaget calls the INRC group. Mathematically it is called the Klein group (Halford, 1978 p.15).

1.2.4 Transitions

According to Piaget, there occurs major changes in the logical reasoning patterns, when the child transits from one stage to another. About the transition from one stage to another he says as follows: 'a phenomenon which was noted empirically or else had been felt to be simply probable, all of a sudden became logically necessary for the child from his point of view. This necessity comes from a closure or completion of a structure' (Piaget, 1971 p.5). He continues to say that the feeling of necessity is neither a subjective illusion nor an innate or a priori idea. It is an idea which is constructed at the same time as the overall structures. As soon as a structure is sufficiently complete for closure to occur or, in other words, once the internal compositions of the structure become independent and independent of external elements and are sufficiently numerous to allow for all types

of arrangements, then the feeling of necessity manifests itself. 'Thus stages are characterised by overall structures which become necessary but which are not so initially. Formal structures become necessary when the structures of identity, of functions, etc., are complete; and those in turn become necessary when the sensorimotor functions are complete. But nothing is given in an a priori or innate fashion; nothing is performed or predetermined in the activity of the baby. For instance, we would search far and wide in the behaviour of the baby without finding even the rudiments of the group of four transformations, or of the combinatorial. These are all constructed and the construction - this I find to be the great mystery of the stages - become more and more necessary with time. The necessity is the end of development, not at the point of departure. This then, is the model upon which we are trying to base our work and our experiments' (Piaget, 1971 p.9). Kuhn (1979), says about transition as follows: 'what is initially a disturbance from the outside gives rise to simple regulations and then to more complex compensatory reactions. These compensations eventually reach a form having complete symmetry, and what are initial disturbances become systematic transforming agents within the system. In other words, they lead to an enriched, more highly differentiated structure.

1.3 Logic and Content of an Individual's Cognitive Structure

The development of an individual's cognitive structure depends on the growth and development of his logical reasoning and the development of conceptual structure[8]. In other words, the cognitive structure of an individual has a grammar and a content part. The grammar is the logical reasoning and the content is the conceptual frame. A minimum of grammar is required for the development of the content (assimilation) and it is through the construction of content structures that the logic developed from a qualitatively lower level to that of a higher level. Also, the conceptual structures undergo modifications as the logic develops[9]. The truth of the above proposition can be brought out clearly by the following illustrations. An individual who has not yet developed the formal operational logic and who operate at the concrete level, will not be able to visualise Newton's laws of motion or the relationship between electronic configuration of atoms and their physical and chemical characteristics. Such an individual needs objects in front of him that are easy to handle, or else be able to visualise objects that have been handled and that are easily imagined without any effort, in order to think (Piaget, 1971 p.4). Development of the logic does not ensure the development of the cognitive structure unless the individual comes across such questions in his interaction with the external world. An adult who has

developed the formal reasoning may not be able to discriminate between a planet and a star by looking up in the night sky or give reasons for the cyclic changes of the phases of the moon, if he had not asked himself questions concerning them and made relevant observations. He might not have noticed the planets and the stars as his cognitive structure had not integrated such a concept, though he is capable of doing so since he has the equipment (logic) to do it.

Piaget (1977), offers three interpretations for such anamolies. 'The slowness in development would be due to the quality and frequency of intellectual stimulation received from adults or obtained from the possibilities available to children for spontaneous activity in their environment. In the case of poor stimulation and activity, it goes without saying that the development of the first three of the four periods will be slowed down. When it comes to formal thought, there will be even greater retardation in its formation; or that perhaps in extremely disadvantageous conditions, such a type of thought will never really take shape or will only develop in those individuals who change their environment while development is still possible' (p.7). The interpretation would suggest that all normal individuals are capable of reaching the level of formal structures 'on the condition that the social environment and acquired experience provide the subject with the cognitive nourishment and intellectual

stimulation necessary for such a construction' (p.8). The second interpretation deals with the diversification of aptitudes with age and that the aptitudes of individuals differentiate progressively with age. Some adolescents are more talented for physics or problems dealing with causality than for logic or mathematics, while others demonstrate the opposite aptitude. The third most probable interpretation would be that 'all normal subjects attain the formal operations stage if not between 11 to 12 and 14 to 15 years, such would be true between 15 to 20 years. However, this would be dependent on their aptitudes and their professional specialisations and the manner in which formal structures are employed mav not necessarily be the same in all cases' (p.9).

1.4 Environment as a Major Influence on Cognitive Development

The above discussion on the development of conceptual structures and the explanation by Piaget (1972) indicates the importance of social environment and acquired experiences on the construction of structures in an individual. In the case of an environment which provides poor stimulation and activity the development is retarded, whereas an environment which can provide cognitive nourishment and intellectual stimulation, will aid development. The social environment would comprise of casual experiences and organised experiences. Casual experiences include those experiences which the individual

derives from his interaction with other members of the society viz., his parents, siblings, peers, etc.; and with objects around him like books, magazines, play objects, etc. Such interactions though important in influencing one's cognitive development are less amenable to manipulation by external sources. The organised environment comprises of formal and non-formal educational settings. Such organised environments should provide cognitively nourishing and intellectually stimulating experiences for an individual to interact and construct his cognitive structures.

1.5 Formal Education as a Potential Medium of an Individual's Interaction with the Environment

One of the main forms of organised social environment is provided by the formal educational system. Formal education aims at developing the personality of an individual which includes physical as well as mental development. Construction of cognitive structures forms a major portion of the development which includes the construction of logical reasoning and the development of conceptual structures. Kuhn (1979) and Kamii (1978) say that the promotion of formal operational reasoning should be the goal of education. Piaget's own views on educational objectives in modern society are probably shared by most educators today. According to him, 'the principal goal of education is to create men who are capable of doing new things, not simply of repeating what

other generations have done - men, who are creative, inventive and discoverers. The second goal of education is to form minds which can be critical, can verify, and not accept every thing they are offered. The great danger today is of slogans, collective opinions, ready made trends of thought. We have to be able to resist individually, to criticise, to distinguish between what is proven and what is not. So we need pupils who are active, who learn early to find out by themselves, partly by their own spontaneous activity and partly through material we set up for them; who learn early to tell what is verifiable and what is simply the first idea to come to them' (Piaget, 1964a p.5).

If the formal education has to aid the construction of cognitive structures by the learner the curriculum frame should be a well connected network of theories, laws, principles, etc., and it has to take into consideration the level of abstraction the children of different grades are capable of. Overloading the curriculum with abstract concepts, especially to those grades where the children are incapable of showing formal reasoning, may aid neither the development of conceptual schemes nor the construction of logical structures. Also, the type of classroom interaction should be able to provide a congenial atmosphere for the active interaction of the learner with the environment. Piaget opines: 'the question comes up whether to teach the structure,

or to present the child with situations where he is active and creates the structure himself. The goal of education is not to increase the amount of knowledge, but to create the possibilities for a child to invent and discover. When we teach too fast, we keep the child from inventing or discovering himself. Teaching means creating situations where structures can be discovered; it does not mean transmitting structures which may be assimilated at nothing other than a verbal level' (Duckworth, 1964).

Engelmann (1971,p.120), says that there are five primary principles derived from Piagetian theory that describe development: 1) learning is subordinated to development and not vice versa, 2) learning is associated with developmental stages and these stages occur in an invariant succession, 3) the logical structure is not the result of physical experience, it cannot be obtained by external reinforcement. The logical structure is reached only through internal equilibration, by self-regulation, 4) it follows that the only way to 'teach' logical structure is through the process of internal equilibration and self-regulation. Conversely, if one observes a child who has acquired 'logical' structure in connection with a specific test, one could conclude that the child had acquired his skills through an internal process of self-regulation, and 5) the structures that are induced through equilibration last a life time.

A great deal of implications can be derived from the above principles for the assessment of a child's development and for curriculum development. The curriculum has to be highly flexible and dynamic. It has to take into account the logical structures of the learner and provide conflicting data or objects, through the manipulation of which cognitive conflicts are created or demonstrate phenomena which would induce cognitive conflicts, so that the self-regulatory mechanism of the learner is activated. In short, the basic principle of curriculum development, which includes the mode of classroom instruction, would be to provide an environment for the learner so that he undergoes the process of scientific inquiry and constructs cognitive structures through the self-regulatory mechanism.

Hooper(1968), stresses accurate assessment of the child's cognitive structure at a given point of time or development. The curriculum sequence should be designed in accordance with the child's changing cognitive status. The task of a teacher becomes one of relating the measures of cognitive function and structure to classroom requirements and schedules and the Piagetian tasks are viewed as diagnostic tools for educational assessment. Piaget(1962), criticises the school system for inhibiting the child's spontaneous development. 'Piaget's tasks could be valuable adjuncts to those measures designed to determine grade or level

placements, subject matter readiness, and corrective or remedial instructional programmes. These considerations apply to such topics as quantity-number readiness, scientific concepts, and causality relationships which have a rather direct connection with their respective curriculum areas (Hooper, 1968 p.424). The particular stage specification indicates when to intervene and what to present for the content area in question. While many topic areas are directly inferable from the content specific areas mentioned earlier, Piaget's system also includes a more general curriculum directive. 'The great power of Piaget's model lies in its inherent generality and potential application to a broad range of achievement areas subordinate to logical thought processes or reasoning' (p.425). The above statement may be further explained with an illustration. A concrete operational student is capable of certain functional capabilities including multiple classification and the ability to perceive and utilise reversible transformations. Training in these particular functional skills through content oriented problems should aid the assimilation of conventional scholastic areas into the learner's cognitive structure. In short, concretisation of content structures should help the learner assimilate these into his cognitive structure. But, a mere didactic presentation of a perfectly organised content sequence would not aid development. Piaget (1964b), is quite clear regarding the

value of straight forward didactic presentations. 'Experience is always necessary for intellectual development ...... but I fear that we may fall into the illusion that being submitted to an experience (a demonstration) is sufficient for a subject to disengage the structure involved. But more than this is required. The subject must be active, must transform things, and find the structure of his own actions on the objects' (Piaget 1964a p.4). It is this cognitive reorganisation by 'self discovery' in the classroom which Piaget stresses as a crucial element. The above contention may be further elaborated with an example. For the concrete operational child, an actual concrete manipulation of the objects or task material is required for his self-discovery. This, in the case of number training, addition-subtraction and multiplication-division experiences should be provided such that the child can actually perform them and reverse their activities. Similarly, multiple classification experiences could be ordered in terms of increasing complexity with the children actually constructing and reconstructing matrices on the basis of single-dimension attributes. Formulation of such tasks would demand considerable ingenuity on the part of the teacher to analyse the content to be learned in terms of the operations implicit upon it. Having done this, the teacher will have to arrange the learning materials so that these operations can actually be carried out by the student himself (Flavell, 1963 p.368).

1.6 Can Mental Operations be Induced?

This is a highly controversial question in the Piagetian theoretical framework. Piaget himself is silent on the question. This may be because his theory of cognitive development could not accommodate the factors which stimulate cognitive development. This observation is based on Piaget's reaction to the question of how transition from one stage to another occurs. Piaget (1971 p.9) says that the necessity for construction of structures from within the individual and he admits that this is 'the great mystery of stages'. Inhelder and her collaborators have later refined the Piagetian theoretical framework and the question of the acceleration of reasoning patterns seems to find a place in the reformed theory. Cellérier (1976), says that recent studies on transition seem to show a common process behind the construction of new rules and concepts by an individual. He says that new rules and concepts arise from recombination of the ones that are present. This recombination relies heavily on the existence of a general-purpose representation system that can code both actions and situations, and a pattern recognition device that acts on these representations to produce rules and concepts - that is, higher order entities such as prescriptions and descriptions. This means the representation system must have some capacity to accommodate new types of input: it must itself be adaptive. Finally,

there must exist a decomposition and recombination device that acts on these descriptions and prescriptions to generate new ones. The actual choice as to which combination should be generated would have to be based on the construction of a succession of partial, reorganised representations (structured models) of the relationship between prescriptions and descriptions. The selection of the adapted combination would depend on an evaluation of their effects on the (external) problem environment, this evaluation being used to update the internal model and start a new recombination sequence. This cyclic chaining of external observations and internal coordinations is emphasised in Piaget's recent reformulation of the equilibration model. This type of analysis gave rise to a picture of cognitive development as a parallel evolution of cognitive categories, each composed of a neat filiation of progressively stronger structures. It has been recently complicated by the discovery that many different schemes and concepts may be applied by the child to the same problem, and that the different cognitive categories seem to evolve at slightly different rates. The net result is that lateral interaction between precursors appear at the decomposition and recombination level. These interactions take place between elements that are heterogeneous in two ways: 1) they originate from different categories; and 2) their degree of completion are not necessarily the same. Thus, Piaget's

picture of development now incorporates vertical relations (intracategory filiations) horizontal ones (intercategory filiations), and oblique ones (interactions between elements of different operatory levels)' (Cellérier, 1976 Pp.41-42).

The question of inducing the construction of logical operations seem to have more relevance in the reformed Piagetian theoretical framework described above. The decomposition and recombination model seems to accommodate this question. Also, the cyclic chaining of external observations and internal coordinations seems to accommodate the same question better than the classical equilibration model. The above observations are based on two reasons: 1) the decomposition-recombination model offers the possibility of the breaking down of the internal contradictions in the constructed cognitive structures of an individual on the basis of a dialectical feedback-evaluation relationship between the external problem environment and the internal model, 2) the idea of filiations which strengthens the structures, gives room for secondary construction on the cognitive structures which at a later point of time may be decomposed and recombined. Such a concept gives scope for learners constructing augmentations to a structure at that point of time when he is confronted with a problem.

A subsequent question that arises to the question of 'inducing' is how far one can induce. Is it infinitely

possible to induce the construction of logical operations? In other words, can formal operations be induced at a very early stage of development of the child. Perhaps the answer is that infinitely one may not be able to induce the construction of logical operations. At least the theory does not permit this. So, within certain limits one may be able to induce cognitive development if the learners are provided with the right type of environment, and their cognitive equipment is ready for transformations. Duckworth(1979 p.302), discussing on the dilemma of 'applying Piaget' asks a similar question: 'Is it possible for a child's understanding .... of necessary relationship to evolve in especially devised situations more than it would spontaneously?' and she says that it is not the pressure of data that gives rise to the understanding. It is, on the contrary, the child's own struggle to make sense of the data. Talking about accleration she says: 'in every case where acceleration takes place, it results from a conflict arising in the child's own mind. It is the child's own effort to resolve a conflict that takes him or her on to another level'. Piaget questions the effect of stimulation on the child's initiative. He asks 'when some notions are facilitated by learning experts, whether they can serve as points of departure for new, spontaneous constructions, or whether the child will then tend to depend upon outside provocation rather than his or her own initiative

in pursuing the relationships among ideas'. Duckworth (1979 p.311), concludes the discussion by saying that 'learning in school need not and should not be different from children's natural forms of learning about the world. We need only broaden and deepen their scope by opening up parts of the world that children may not, on their own, have thought of thinking about'. She does not mention about any specific ways of deepening the children's scope of 'opening up parts of the world'. However, specific ways and means of inducing the construction of cognitive structures are discussed in the following chapter in the form of empirical evidences.

Notes

1. Here, the 'human mind' is not to be taken as an individual's mind, but, the mind of the human species.

2. Here, 'cognitive structures' refer to an individual's construction of logico-mathematical structures and the construction of physical reality by actively interacting with the environment.

3. Here, the period 9-12 months is not to be taken as refering to an individual child's development. Rather, it is the norm for that population.

4. The use of the term 'stage' should not be taken to imply that the development in question is a sudden affair. The term refers primarily to a similarity in the underlying process of the reasoning (structure) and presumably, to an organisation of nervous process that is common to all and only secondary to a relative synchronicity of development.

5. Here the term 'scheme' refers to a systematic or orderly arrangement of the elements of a body of knowledge.

6. The logico-mathematical system or logico-mathematical structures are progressively constructed by an individual through his cognitive action with the environment.

7. Here the term 'schema' refers to Piaget's term for the sensory motor coordinations present within the child at birth.

8. Here the term 'logical reasoning' or 'logical operations' refer to any computational operation such as addition or subtraction, or non computational operation such as, comparing, selecting, and extracting.

9. Here the 'conceptual structure' refers to the idea of hierarchical nature of concepts of David Ausubel.

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CHAPTER II

EMPIRICAL EVIDENCES

2.0 Introduction

The previous chapter describes the Piagetian cognitive development model and discusses the possibility of 'inducing' cognitive development (within certain limits) as a theoretical proposition. What is presented in this chapter is an empirical support to this proposition in the form of a review of research reports. An exhaustive survey of related studies is not attempted as there are umpteen studies. Instead, a few exemplars are chosen to show a trend in the evolution of 'acceleration studies' (though not in a chronological order), with a view to deriving certain principles for the development of a classroom instructional model which would aid cognitive development. The studies reviewed in this chapter are broadly classified into two classes viz., 1) studies conducted abroad and 2) studies on Indian population. In the latter class all types of Piagetian studies are included to indicate the status of researches related to a Piagetian framework in India.

2.1. Effect of Structured Experiences on Reasoning

In the '50s and '60s, a number of investigators tried to induce Piagetian concepts under laboratory conditions. These attempts were largely unsuccessful (Goldschmid, 1971

p.104). Flavell (1963), has reviewed these early efforts and concluded that "Piagetian concepts have so far proved inordinately difficult to stamp in, whatever the training procedure used" (p.378). But, if one closely examines these studies reviewed one can find that the training procedures used were more or less "perfect roads to learning". That is, the learning sequences are arranged in a perfectly logical manner (according to the logic of the one who frames these sequences and not according to the logic of the learners). Several attempts were made by researchers in the '70s also but, they met with little success, Nous and Raven (1973), studied the effect of structured learning sequences on the reasoning of V, VII and IX graders. They report that only a few of the IX graders could benefit from the training and none from the V or the VII. They attribute the difference to the reasoning abilities of the students before training. Hammon and Raven (1973), report that only a few among grade VIII students who were capable of formal reasoning could improve their reasoning through structured learning sequences. Hall (1973), attempted to improve the conservation ability in the VI and VII graders through six months of teaching elementary chemistry using programmed instructional material. He found that they did not attain conservation of chemical identity in spite of prolonged treatment. Walker (1979), tried to study the effect of readymade learning kit

on genetics on Piagetian cognitive development in college students. An 'unexpected finding' of the study is that the ability of students to operate at formal level is not related to the learning of problems. Lehman(1980) failed to aid the cognitive development through an audio-tutorial instructional strategy, though the individual was the focus of the instruction. Levine and Linn (1977); and Linn(1980a), reviewing studies conducted to improve reasoning through structured learning sequences in science and mathematics related concepts mention that these studies could produce only very limited success. They mention that such structured sequences may be beneficial to those who alrady show signs of formal reasoning and not to the concrete operational learners. The above statement is supported by a few empirical evidences. Biran constructed a successful learning programme which demonstrated the designing of experiments, the testing of hypotheses and the drawing of conclusions, Grey found that adolescents, subjected to programmed texts for training judgement, obtained higher scores on thinking problems. Anderson administered instruction in thinking to pupils and the results showed considerable influence on the maturity of judgement. Stones gave programmed instruction in relevant historical concepts and increased the maturity of historical judgement in a group of secondary pupils (Modgil and Modgil, 1976 p.177). A few observations that could be made regarding these four studies which differentiate them from the studies

reported earlier, are; 1) these programmes have incorporated an element of discovery 2) they were problem oriented and 3) these programmes were presented to learners who had shown signs of formal operational reasoning. Linn (1980c), comments on the failure of instructional strategies by saying that students do not get a clear idea as to how they can use the learnt strategies to new problems since the problems given in the strategies are not formulated by them. Rather these problems are presented to them. Linn (1982), on reviewing a few more studies mention that instruction which combines strategy training with application training succeeds more consistently than either by itself. Linn and Thier(1975) and Linn (1980b, 1980c), suggest that success can be obtained better with instructional interactions involving effective diagnosis of the inaccurate rules used by the students. Lehman(1980) attributes lack of flexibility in the strategies to the poor performance of students in reasoning tests.

The failure (mostly) of adolescent students to improve their reasoning with these structured instructional strategies shows the importance and need of 'active participation' (in the cognitive sense of the term) on the part of the students in order to develop their cognitive structures or reasoning patterns. Prestructured problems may not appeal as problems to the students. The findings are in agreement with the theoretical contention by Piaget that 'to know an object is

to act on it - to modify it, to transform it, to understand the process of transformation and in turn to understand the way it is constructed. Operation is the essence of knowledge - an interiorised action which modifies the object of knowledge. Operation is interiorised but reversible action. This does not occur in isolation but as part of the total structure with logical interlinks. These operational structures are the basis of knowledge' (Piaget, 1964 p.181). Prescribed problems may remain isolated from the learner's cognitive structure unless he acts on it and the problem occurs as a hurdle in the way of explaining a phenomenon. The problem designers frame the problems according to their cognitive structures which are not likely to appeal as problems to the learners, since the problem designers have made no attempt to understand the cognitive structures of the learner. About the difficulty in one individual organising experiences for another, Dall (1972) says, "there is a strong temptation to assume that presenting subject matter in its perfected form provided a royal road to learning. This is the difficulty with programmed instruction, or even with text book instruction. However, there is also another temptation for all goal oriented educators, and that is to assume that the psychological organisation can be done, or made more efficient, if one individual does it for another. But the very nature of the concept requires that the individual does his own organising. Not only is there no royal road to

learning, neither are there maps which the individual must merely memorise".

2.2 Previous Knowledge on Learning

The failure of structured learning sequences in effecting cognitive modifications may be attributed to different reasons. For instance, prescriptive problems do not appeal as problems to the students, as they do not get the opportunity to organise the structure of concepts. Rather it is already organised for them. This indicates the need for understanding the cognitive structures of the learners' prior to instruction. In this context, an observation on Ausubel's theory is of relevance. 'If I had to reduce all the educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly' Ausubel (1968).

Posner et. al.(1982), stress the importance of using students prior knowledge in developing learning strategies. They developed a model of learning where learning is not simply an addition of bits of information, but involves the interaction of new knowledge with the existing knowledge. They report a little success in developing cognitive structures using this model. Hewson and Hewson (1983), using the same model of strategy development conducted an

experiment which reveals that learning strategies developed on the prior knowledge of students aided cognitive development whereas strategies developed without considering the prior knowledge of students failed to do so. Pines(1978), developed an audio-tutorial instructional package in science concepts based on the prior knowledge of learners. On studying the relationship between prior knowledge and the development of cognitive structures he reports that, relationships exist between prior knowledge and resulting cognitive structures subsequent to instruction because relevant cognitive structures affect learning. Others who report similar findings are: Wesney(1978) and Schwartz(1980).

2.3 Existing Structures Influence Development

Piaget calls his developmental epistemology "naturalist but not positivist". Cognitive behaviour is an outward sign of the assimilatory and accommodatory capacities of a living organism. The biological aspect of Piaget's theory is often difficult to grasp for those psychologists who believe that mental development is infinitely malleable under favourable conditions and with adequate teaching methods, and who are convinced that what they think of as errors of growth can easily be corrected. A biologically inspired theory that uses concepts such as assimilation, accommodation, and action schemes is very different from a learning theory that tries to account for cognitive development in terms of

associations, connections, and conditioning. The latter type of mechanism always suppose that two events are linked in the subject's mind because he has passively submitted to an outside pressure connecting the two, The concept of assimilation, by contrast, supposes that the subject actively assimilates a new event to already existing structures. There is thus an interaction between the knowing subject and the objects that are to be known. As knowledge of these objects proceeds, the subject's activity becomes better and better organised. This justifies Piaget's theoretical distinction between two types of knowledge: logico-mathematical knowledge and the knowledge of the physical world. "From the Piagetian point of view, these types of knowledge are the result, on the one hand, of the organisation of the subject's activities (logico-mathematical knowledge resulting from reflective abstraction) and, on the other hand, of the knowledge the subject gains about the object's properties (knowledge of the physical world resulting from physical abstraction)" (Inhelder, 1977 p.54).

The above discussion clearly indicates the importance of logico-mathematical knowledge in addition to the knowledge of the physical world in the construction of cognitive structures. How the dialectical relationship between these two knowledge structures influences the cognitive development

is brought out through the following empirical evidences and many others discussed in the sections to follow.

Nurrenbern (1980), investigating the problem solving behaviour of concrete and formal operational high school chemistry students, reports that formal operational students approach the problem differently from concrete operational students. The formal operational students are able to reshape the problem and derive more meaning out of it whereas concrete operational students fail to do so. Morin (1978) also reports similar findings after investigating the problem solving abilities of different students using problems requiring formal thinking abilities. Barber (1980) studying the relationship of differential treatments with concrete and formal biology concepts using concrete and formal language on the cognitive development of concrete and formal operational students, reports that concrete operational students could construct concrete concepts when taught through concrete language whereas they fail to construct formal concepts either through formal or concrete language. But, formal operational students benefited from both the treatments. Hayes (1980), studied the effect of two methods of instruction in the achievement of formal and concrete operational thinkers and reports that the teaching methods did not make any difference to the concrete and formal operational students. He mentions that the cognitive level of the learner and the suitability of the conceptual level

of the material to be learnt seem to be important factors rather than the mode of instruction. Besmajian(1978), gave an audio-tutorial package to the concrete as well as the formal learners and found that the formal learners gained better from the package. He attributes the difference to the difference in the cognitive capabilities between concrete and formal learners. Pastore(1976), gave differential treatment to early concrete operational and early formal operational students. Concrete organisers were presented to concrete learners and formal organisers to formal learners. He reports that concrete learners having received concrete organisers performed at a higher level than those who received formal organisers and early formal students performed better having received abstract organisers. The above studies clearly indicate that a minimum of development of the logico-mathematical structures are required for the assimilation of abstract concepts or for the construction of abstract structures.

2.4 Role of Manipulation of Objects on Cognitive Development

The equilibration model of Piaget clearly indicates the importance of 'acting upon' objects and ideas. Researchers who attempted to show differential effects for concrete and formal students with the manipulation of models are Sheehan (1970) and Goodstein and Howe(1978). Sheehan found that manipulation of models was beneficial for both concrete and

formal thinkers whereas Goodstein and Howe found that only the formal students benefited from manipulation. Gabel and Sherwood (1980) hypothesised that prolonged manipulation of models might develop the reasoning of concrete students. He taught chemical concepts to high school children by allowing them to manipulate objects for almost one year and found that concrete and formal students benefited. Cantu and Herron (1978), identified concrete and formal operational students. they found that concretisation of concepts helps both types of learners.

The above mentioned studies support the theoretical contention that concrete operational learners may fail to deduce propositional generalisations out of the manipulation with concrete objects, though they may be successful in making concrete generalisations. In order to help concrete learners the concretisation of data might have to be done in such a way that the data presented conflicts with their cognitive structures. Several such attempts at creating cognitive conflicts might initiate changes in the cognitive structures of such learners to resolve their conflicts and discover a new rule. The newly transformed cognitive structure may be able to assimilate the new set of observations better. The above mentioned studies do not report such discoveries by the students except, perhaps, by Gabel and Sherwood where the discovery is more due to

prolonged treatment rather than the manner in which data was supplied to the learners.

2.5 Discovery Learning on the Development of Reasoning

Discovery learning is one of the most widely used techniques to improve reasoning. A wide variety of discovery techniques are used by different researchers, ranging from discovery through prescriptive problems, guided discovery, to pure discovery where the learner frames problems on his own and goes on solving them on his own. From an instructional point of view two types of problems are used in discovery learning by researchers viz., 1) using puzzles or riddles to be solved by the learners (Beasley, 1979) and 2) where problems related to classroom instruction are used.

Rodriguez and Lovell (1983), tried to improve the classification ability and science vocabulory in grade III children using an enquiry approach to teaching and found that through such instruction learners improve their classification ability as well as their science vocabulory. Other studies which report similar findings are Salib(1979) who reports discovery better than expository in accélerating reasoning and Bachuroff (1980) who reports that inquiry based laboratory investigation enhanced the cognitive development of learners.

Charoenpit (1979), taught concrete and formal

operational students using enquiry and traditional methods. The design of the study was a 2X2 factorial design. He found no difference between traditional and enquiry approach. A similar study is reported by Schneider and Renner (1980) where they compare enquiry approach to exposition. They taught four physics units to two groups of IX graders, (80% of them concrete operational) using the differential treatments and found that there was no significant difference between the two groups in achievement and intellectual development. Blake and Nordland (1978), found no development in a sample of college freshmen who were taught through enquiry approach. Other studies which report similar findings are: 1) Bock (1980), who reports no difference between traditional laboratory approach to teaching and enquiry laboratory approach to teaching; 2) Johnston (1980), who reports that enquiry is suitable only to those students who are capable of formal reasoning; and 3) Wise (1979), who reports that only formal operational students could discover rules of formal nature. Wolfinger (1979), tried to train young children (III and IV graders) on physical causality using science teaching with a discovery approach and he failed. The failure is attributed to the lack of development of proper cognitive structures in the learners. But, Gann (1980) could develop 'physical causality' in IV graders. The success is attributed to students themselves framing

hypotheses and testing them. Abdullah and Lowell(1981), succeeded in making 5-6 year olds make concrete generalisations about 'insect' and 'animals' using coloured pictures and models.

The two groups of studies discussed above seem to display a contradictory picture regarding the effectiveness of 'enquiry approach' in the development of cognitive structures. But, if one closely examines these studies, they indicate that a mere discovery approach to instruction may not aid cognitive development as hypothesised by many. This is mainly because of the lack of 'appeal' the prescribed problems have to the cognitive structures of the learners'. In other words, the prescribed problems may not appear as 'problems' (in the cognitive sense of the term) at all to the learners who have not acted on the information provided to derive a problem. Still, through a prescribed route of finding results they may succeed in finding solutions. But, the process of tackling a problem on finding alternate solutions and testing them remains alien to their cognitive structures. Mayer(1983), reviewing discovery learning literature on science-oriented learning tasks reveals that, 'discovery sometimes resulted in high performance and sometimes seemed to fail. Pure discovery does not take care of the previous knowledge - guided discovery is better. There is a clear and consistent evidence for the superiority of

guided discovery procedures' (p.226). In order to aid development the problems will have to emerge as problems or hurdles when the learner tries to explain a certain set of data by acting upon the data with his cognitive structure. The above statement is supported by the study conducted by Bady(1979a). He says that previous researches show that high school students even after training fail to understand hypothetico-deduction. He encouraged IX graders to formulate hypotheses to problems and test these hypotheses at their own speed and will and reports that cognitive development occurred. That is, they developed their combinatorial reasoning ability to a formal operational level through this hypothetico-deduction exercises. Bady(1979b), shows how the ability to test hypotheses can be developed in high school students by posing problems that suit the cognitive structures of the learners'.

2.6 Creating Cognitive Conflict as a Means of Cognitive Development

Cognitive conflict arises when a learner comes across an information which creates a dissonance with his previously held notion or assumption. There can be three possibilities when a learner comes across such an information 1) it is rejected as invalid, 2) the existing cognitive structure is stretched to assimilate the contradictory information (here the cognitive structure is not modified to accommodate the

conflicting data) and 3) there arises a need to transform his cognitive structure whereby he can accommodate the new information. By the third alternative the cognitive structure develops state of lower equilibrium to that of a higher one. The second alternative gives scope for creating further cognitive conflicts because the 'stretched cognitive structures' are unstable and are more prone to development than the cases where the learners offer the first alternative to conflicting information.

Cognitive conflict was used by Gruen(1965) to develop conservation of number in children of the age range 5-6 years with success. Smedslund (1961a, 1961b) succeeded in developing conservation of substance and weight in children between the age range five years six months, and six years six months using a cognitive conflicting treatment. Mermelstien and Mayer (1969) used similar instructional situations to develop conservation ability like conservation of number, length and area to children of different age groups with success. Inhelder and Sinclair(1969) developed a strategy for inducing cognitive conflicts. Strauss(1972) used this strategy for developing the concept of 'animism' in young children of the age range seven to eight years. He could develop the concept in them. Bredderman(1973) used a similar strategy of teaching to develop the ability to control variables among young adolescent children with success. Other studies which report

similar findings using cognitive conflict strategy are Inhelder et. al. (1974); Karmiloff-Smith & Inhelder (1974); Strauss and Ilan (1975); Murray et. al. (1977); Snyder and Feldman (1977); and Johnson and Howe (1978).

Almost all the above mentioned studies were conducted under laboratory conditions and the individual children were given training alone or in small groups of two or three. The question of whether such a strategy could be used in a group instructional situation was asked by Rowell and Dawson (1981). The questions they raised in their study were 1) can cognitive conflict strategy accelerate conservation abilities? 2) does learning result from classroom presentation? 3) does pretest affect further learning? They tried to develop volume conservation in VIII grade students of Australia and found that acceleration is possible even through group instruction using cognitive conflict strategy.

Bass and Montague(1972), Case and Fry (1973), Lawson et. al. (1975), and Nous and Raven (1973) employed a variety of training methods. Those which were successful in their attempts shared several common characteristics. The first common characteristic is physical interaction i.e., subjects manipulating physical objects or at least viewing demonstrations. The second common characteristic is peer interaction used to induce cognitive conflicts. This is what Piaget calls 'social transmission'. Peer interaction seems to

function by introducing the subject to ideas or hypotheses which are different from their own, thus producing a cognitive conflict. This conflict would promote cognitive development through the process of equilibration or self regulation. Gabel and Sherwood (1980), and Howe and Durr (1982), used peer interaction to induce cognitive conflict. The peer interaction is designed to induce the child to question the premises or assumption upon which he based a premise, judgement or cohesion. They report that the peer interaction is useful even in the middle school level. Both these studies report acceleration of concepts as well as reasoning. Atkin and Karplus (1962) and Lawson and Renner (1975), developed a classroom instruction model called 'learning cycles'. This model divides instruction into three phases: 1) exploration 2) invention and 3) discovery (application). During the exploration phase, the student manipulates physical material provided in the experiment. He is asked to manipulate certain variables in the experiment and observe and record the results. During this period, the student will encounter new information which is not directly assimilable. Through the process of self regulation, existing structures will be altered (accommodation) to allow assimilation to occur. The cognitive conflict which initiates the self regulation process can occur through direct observation of physical phenomena or through social interaction (student-student or instructor-

student). Cognitive conflict and social interaction are not limited to the exploration phase, but can be employed during all three phases. At some point during the exploration phase, the student is asked to try to order the information he has collected into some useful pattern. If the student is unable to devise a method of ordering the information, the instructor may suggest one, but only after the student has made initial attempt. If appropriate, the instructor may also furnish a label for the newly invented concept. These activities constitute the invention phase. To further strengthen the students' grasp of the new concept, he is asked to apply it to new situations in an attempt to discover its usefulness and limitations. This is the discovery phase. The underlying construct of the learning cycle is that through a series of successive equilibrations the student will develop a more refined cognitive structure (Karplus, 1977 p.172). Karplus refers to the three phases as exploration, concept introduction and concept application which seems to define the functions and properties of each phase more clearly.

Studies by McKinnon and Renner (1971) and Smith and Von Egerene (1977), found that by using the 'learning cycle' strategy to instruction one could accelerate concrete students to think more abstractly and therefore transform from concrete to the formal operational stage. In these studies the reasoning

patterns accelerated are 1) controlling of variables, 2) propositional reasoning, 3) combinatorial reasoning and 4) hypothetico deduction. Ward used the 'learning cycle' in teáching chemistry to high school students and found that formal operational students show higher achievement on items requiring concrete thought than concrete operational students. They out performed in the formal items also. Many concrete operational students showed improvement though formal students out performed them. Ward (1979), used the same strategy on 208 students of the chemistry graduate course and found that peer interaction helped in accelerating concrete operational students to formal.

Wollman and Chen (1982), developed a classroom approach of social interaction. This approach comprises of four phases: a) asking pupils why something happened b) asking for a justification c) suggesting an alternative explanation with evidences and d) accepting an alternative only after ruling out all other possible explanations. They compared such an approach of instruction to personalised instruction on II graders in an effort to accelerate the ability to control variables. They report that, the effect of 'social instruction' treatment was quite substantial in comparison with the effects of personalised instruction.

2.7 Acceleration of Mental Operations

The previous section of this chapter (section 2.6) discusses at least three models of instruction that were used by different researchers for accelerating logical operations in learners. They are: 1) 'cognitive conflict' strategy developed by Inhelder and Sinclair (1969); 2) 'learning cycles' developed by Atkin and Karplus (1962) and Lawson and Renner (1975); and 3) 'social interaction' model developed by Wollman and Chen (1982). A lot of implications can be derived from these models to construct an instructional model under any given educational setting. The development of an instructional model to suit the Indian urban classroom setting is discussed in the forthcoming chapter. In this context it would be worthwhile to note the conditions given by Kimball (1973) in developing an instructional model to accelerate logical operations. He says "an individual who is to be introduced to formal operations must be facile with concrete operations: able and experienced in manipulating materials; capable of formulating generalisations; conserves number as well as area, shape, substance and volume; classifies according to multi-attributes; identifies variables; identifies relationships and manipulates them in novel ways; exhibits reversibility. An environment that encourages formal thought must now be provided: 1) A facilitator who himself is formally

operational. He is a learner as well as a teacher. He allows many divergent responses, keeping those which meet the criteria set up. He accepts each person even though that person's findings may not 'fit' or 'work' in this situation; 2) Surroundings are rich in material and ideas that encourage manipulation (first hand), interaction and interchange; 3) The learning atmosphere allows for risk taking and creativity; 4) Constructive intervention takes place between learner and environment and amongst learners in a sensitive manner; 5) criteria for acceptable results are set up by all learners in the situation; 6)'Messing around' is encouraged so that learners can 'feel' the problem as well as 'think' it; 7) Learner is actively involved in coming to conclusions and testing conclusions in new situations. His activity is reinforced 'neutrally' by the teacher; 8) The type of materials present are chosen because they encourage and suggest formal thought, not stand in the way of it. Learning is tailored for the individual; 9) Evaluation tools are available to measure formal thought so that feedback is immediate and personal as well as shared; 10) The learner is placed in a situation of mild conflict and controversy with the materials and the ideas of his colleagues; 11) The training is from simple to complex: from concrete to abstract; 12) Environment allows for curiosity to be met with open discussion, mutual criticism, or support. Final arbitration is by replication with materials" (pp.231-232).

2.8 Studies Conducted in India with a Piagetian Theoretical Framework

Though in the international scene, there are umpteen studies conducted on a Piagetian theoretical framework, this trend does not seem to have caught up in India. A survey of studies conducted in this country reveals that there are only very few studies reported with a Piagetian framework. Among these studies intervention studies are still fewer. For the sake of clarity of presentation these studies have been classified into three groups viz., 1) psychometric, 2) correlational, and 3) intervention.

2.8.1 Psychometric studies

Vaidya (1974), studied certain aspects of thinking among science students of adolescent age. He factor analysed the process of thought of hundred boys and hundred girls of the age group ten to fifteen years from grades VI to X. He reports that more than 70% of X graders could not test hypotheses and generally the adolescent pupils failed to take the logical way of attacking problems. He attributes this to the status of science education. Vaidya (1979) and Sandhu (1981), attempted to factor analyse the adolescent thought. Vaidya reported loadings on ten different factors whereas Sandhu reports a unifactor structure to the adolescent thinking.

2.8.2 correlational studies

A few studies report various relationships of cognitive abilities and other variables associated in the theoretical framework. Syamala (1961), studied the development of concepts like dreams, God, etc., in a Piagetian framework. She reports that environmental factors influence the development of these concepts. Misra (1968), studied the significance of cultural background in the learning process. Mathur and Jain (1969), studied the development of 'conservation' in rural and urban school children and report differences in the development of this ability in these two groups. Rath (1972), also studied the cultural influences on cognitive growth and learning of primary school children in Orissa. He reports that cultural influences affect the cognitive development as well as learning of primary children. Chatterjee (1973) studied the development of the concept of time from early to late childhood to locate a transitional age and report that the development is gradual and a transition occurs at the age of seven to eight years and the true concept develops at the age of ten. Nalinidevi (1976), studied the development of the concept of number in school going and non school going young children and found that there is no difference in the development of the concept in the two groups. Pandey (1979), studied the classificatory ability

among six to ten year olds and reports that the ability is independent of sex; socio-economic status does not have any effect on the classificatory ability. Grade and age has effect on the classificatory ability i.e., the higher the age and grade the better they performed. Sandeep (1979) studied the relationship between classroom interaction and cognitive development. He reports that classroom interaction adversely affects the attainment of perceptual and cognitive skills. Reddy (1980) studied certain factors related to the development of concept generalisation among adults. Chand (1980) studied the development of the concept of movement among children of a wide age range (4+ to 15+ years) and found that around the age of five to seven years there was a change in the concept of movement; and formal reasoning did not develop even at the age of sixteen years. Amin (1982) studied the relationship between spatial egocentrism and conservation abilities in school children and reports that conservation abilities are related to the spatial egocentrism of school children. Banerji and Jain (1982), studied the development of conservation of number, mass and volume in rural and urban school children between the age range five to twelve years. They report differences in the conservation of number and mass between rural and urban children and no difference in the conservation of volume. Dash and Dash (1983), investigated the development of conceptual levels of representation described by Piaget

and Bruner. Each concept level had five similes varying from the most concrete to the most abstract. Young children preferred concrete similes and older ones abstract. Such a shift is attributed to change from concrete to formal reasoning.

2.8.3 Intervention studies

Kamalakanthan (1968), studied the effect of problem solving on physics concept attainment of students and reports that problem solving helped achieve the objectives of teaching science. Rao (1975), designed an experiment to study the effect of transfer of conservation of length, mass, weight and number on conservation of volume. The verbal training is reported to be more productive than the nonverbal training. Bevli (1978), tried to accelerate the acquisition of the concept of speed in children of ages 6+ to 9+ and found that the training was effective. However, it was less effective with socially disadvantaged children. Ajwani (1979), tried to develop the problem solving ability using three strategies: a) by giving specific direction b) by helping to find the method of solution and c) through learning puzzles. He reports that all the experimental groups bettered in problem solving ability. The decreasing effectiveness of the three strategies were in the order b,c,a. Jha (1979), compared an activity based approach in teaching school science and found strong

evidences in favour of such an approach in achieving application of knowledge and in the development of scientific skills. Rath and Patnaik (1979), studied the effect of training on the conservation of volume and length and report that training could bring about improvement in the conservation ability of primary children. Bala (1980), compared the effect of 'modern' and traditional mathematics curricula on concrete and formal logical thinking of children and found that modern mathematics facilitated thinking ability of concrete thinkers (grade IV) whereas it made no difference to the formal thinkers. Padmini (1980), through an intervention programme tried to develop the concept of length, area, volume, weight, the sense of belonging and spatial relationships among primary school children. She used a long term (6 months) intervention programme and found that the experiment was successful in fostering cognitive development. Mohanty and Chaudhary (1981), studied the effect of two training techniques viz., 'screening' and 'self transformation' in inducing conservation abilities in children. The transitional children were given training and found that both the techniques had significant effects. Bhattacharya (1982), used audio-visual methods to teach fractions and decimals to primary children and found that he could accelerate the acquisition of these concepts. Yadav (1982), compared a guided discovery approach to lecture in attaining higher level objectives and reports that guided

discovery is better in attaining concepts. Bhat (1982), used a comprehensive strategy for accelerating area conservation in transitional children of III and IV graders. The strategy consisted of equality and reversibility training, addition/subtraction training (the meaning of which is not purely mathematical), and training through cognitive conflict. These three procedures were used on each day (forty minutes of instruction) in the order given above and, lasted for a total of three days for an experimental group. He reports that both the III and IV graders showed significant improvement in area conservation with the treatment.

The review of acceleration studies conducted in India shows the lack of a common paradigm. The attempts seem to be rather sporadic. Though the classroom was used for acceleration in these studies there is no attempt at reorganising the prescribed curricular experiences. In short, the above studies seem to reflect an educational psychologist's perspective and not that of an educationist's - that is, to focus on the present day constraints in the actual classrooms and frame a suitable model of instruction to suit the needs of the classrooms and also to reorganise the curriculum frame based on a sound theory of instruction. It is in this background that an acceleration study is planned for the present investigation and is discussed in detail in the subsequent chapters.

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CHAPTER III

THE PROBLEM

3.0 Introduction

Having taken the theoretical framework discussed in Chapter I and the empirical evidences in Chapter II as a backdrop, what is presented in this chapter is the problem of the present investigation. A brief discussion on the acceleration studies conducted in India is presented to highlight the lack of field attempts at accelerating the development of cognitive structures in learners. This is followed by a discussion on the need for conducting an experiment in the actual field conditions. The field conditions are then reviewed with special reference to the Baroda city secondary schools as the present investigation is conducted in Baroda. Based on the field conditions and deriving principles from the theoretical framework and the empirical support, a plausible model for conducting an acceleration experiment, in the field conditions, is discussed. This is followed by the presentation of the title, objectives and hypotheses of the present investigation.

3.1 Acceleration Studies in India

Almost all the acceleration studies conducted in India within the Piagetian theoretical framework have made no

attempt to relate the training strategies to the curriculum frame. The experimental inputs or the 'treatments' has been specially designed for the purpose, with very little or no relationship with the content structure of the grade to which these inputs have been given. A reorganisation of the curriculum frame is not attempted to develop the training strategies thus taking the experimental treatment 'away' from the real classroom. Among the studies reviewed there are three studies (Jha, 1979; Bala, 1980; and Bhattacharya, 1982) where an attempt at reorganising the curriculum experiences has been made. But, these studies were aimed at concept acceleration rather than the acceleration of logical reasoning. The feasibility of accelerating the logical reasoning of students in a classroom setting through curricular experiences is still an unanswered question in the Indian Context.

3.2 Need for Field Studies

The difficulty of integrating or adapting experimental results into the actual field has been expressed by many. Campbell and Stanley (1965) say that the direct contributions from controlled experimentation to the field conditions have been disappointing. The claims made for the rate and degree of progress which would result from

experiment were exaggerated and were accompanied by an unjustified depreciation of non experimental wisdom. Finkelman (1978) says that the simplification inherent in the experimental situation often results in the focusing of an isolated, arbitrary or trivial aspect of the phenomena under study. Even if the experiment does get at basic processes these rarely occur in isolation with other processes, and it may render the experimental results of little value for understanding real-world phenomena. Yadav et. al. (1981) say that studies conducted in actual conditions would give scope for a much larger number of variables to operate resulting in a very complex interplay, and thus may bring out new patterns of relationships, different from those which emerge in controlled conditions.

The above discussion shows how the relationships one studies under strict laboratory conditions vary from field conditions and there arises a need for studying the relationship in actual field conditions. Even the field conditions in different settings vary and therefore, the results obtained from the field conditions elsewhere may not find much of a relevance in India. So, an assessment of the field conditions in India is required before formulating an acceleration experiment in the actual classroom.

3.3 Field Conditions in an Urban Classroom in India

The curriculum frame in the Indian schools is highly centralised and the schools have practically no freedom to reorganise the prescribed curriculum frame. The curriculum frame for the schools affiliated to the respective state boards of secondary education are prepared by the board in active collaboration and/or in consultation with the State Institutes of Education (S.I.E.s) and the National Council of Educational Research and Training (N.C.E.R.T.), New Delhi. The schools affiliated to the Central Board of Secondary Education (C.B.S.E.) passively receive the curriculum frame prepared by the Board in consultation with the N.C.E.R.T. The text books for different grades, which form part of the curriculum frame, are also prepared by centralised agencies like the N.C.E.R.T. and the S.I.E.s and the text book boards of different states. Mehta (1983, Pp. 35-47) discusses the state of 'nationalisation' of school text books in India. She shows that the centralised text book agencies like N.C.E.R.T. and the text book boards generally prepare only one set of text books for each grade or standard and there are very few states like Meghalaya and Tripura preparing text books with the help of private agencies. The evaluation system, which also forms an integral part of the curriculum frame, is also highly centralised (in the form of 'public

examinations' conducted at the end of secondary education i.e., grade X) and the whole instruction is directed towards this 'public examination'. The above discussion indicates how the text books, examinations and the classroom instruction which forms part of the curriculum frame are designed and controlled by centralised agencies which make the framework very rigid and static. Menon et. al. (1985) make another observation regarding the school curricula - for instance the science curricula - that it is taken to be just an assemblage of information with no central theme cutting across them. It is not appreciated sufficiently that every curriculum should have an underlying theme depending upon the objectives of teaching that subject from the context. Moreover, curriculum should not be taken just as a static course outline or a text book but also as involving tested suggestions of instructional process alternatives'. Reviewing the curriculum researches conducted in India they observe that 'the limitations of the present day curriculum research in India seem to be a consequence of a highly state controlled, centralised and bureaucratic set up of Indian Education. Most professional research institutions do not seem to enjoy autonomy to try out alternative models of curricula because of the inertia offered by the school system. Moreover, there is hardly any school which is permitted to frame its own curriculum. Hence,

the whole enterprise seems to have caught up in a highly inert structure'. They conclude the discussion by mentioning that what is needed in India is diverse models of curricula to suit the diverse needs.

Kapadia (1971) and Patel (1979) on analysing the science text books of the Gujarat board report that they are badly prepared. They found that students often get confused with the content matter presented in the text books because of its lack of logical organisation. Kapadia reports that the authors of the different sections of a text book in science have no co-ordination among themselves. Such a science curriculum frame and text book imposes a heavy pressure on the teacher to 'complete the course'.

The internal evaluation system in a school is centered around testing the rote memory of a student. This includes the classroom questions asked by a teacher to evaluate the effectiveness of his teaching. Kaul (1975) reports, after conducting an enquiry into the questioning behaviour of the teachers that only 8.7% of the time of classroom instruction is used by science teachers to ask questions out of which more than 87% of the questions are of recall type. Kapadia reports that the questions asked in the annual examinations (terminal examinations conducted by the schools) and other tests are very 'textual'. The questions

are repeated over years and therefore students tend to predict the questions and thereby leave a bulk of the syllabus unlearnt.

Apart from the rigidity imposed by the curriculum frame there are several other constraints on the working teacher to attempt at reorganising the curriculum with a view of developing the cognitive structure of the learners'. One such constraint is the work load of a secondary school teacher. Baxi (1959) and Kapadia (1971) report that the work load of a secondary school teacher is about 20 to 22 hours of teaching per week. It is also reported that the teachers are given other work in addition to the teaching load in the form of organising various other activities of the school, like fee collection. The teacher gets hardly any time to pay individual attention to the students. Another constraint imposed on the working teacher is the faith the school authorities, students and the members of the society at large who are concerned with the education of their wards, place on the text book. A teacher who would like to reorganise the curriculum frame is compelled not to do so by these forces. A third constraint on the teacher is concerning the teacher-pupil ratio in an urban classroom. Gandhi (1968) reports that the number of students in a classroom range from thirtyfive to seventy. Such a high ratio prevents the teacher

from organising activities for each individual student so that he can discover the rules and principles and thus construct his cognitive structure from his actions. Also, it may be mentioned here that very few secondary schools in India are equipped with laboratory facilities for such a large number of students to do experiments and discover the laws, principles, etc., in science (Gandhi, 1968 and Patel, 1971).

The field conditions in India seem to be markedly different from those in other countries where real classroom experiments on accelerating the logical reasoning of learners have been tried out (discussed in detail in the previous chapter). The curriculum frame is outdated and disorganised. There is a lack of a theory base in the curriculum framing. The curriculum demands a lot of hard work from the students in rote memorising the facts, principles, etc. There is hardly any provision for the students to act upon objects and ideas and discover the laws and principles of natural phenomena. The curriculum experiences are rather prescriptive and curb the students from thinking in an original manner.

3.4 Is Acceleration Possible Under These Conditiohs?

This question whether it is possible to influence the cognitive development of the learners under the field conditions described above is not answered as there is

practically no empirical evidence to support it. But, studies conducted under laboratory conditions or quasi-laboratory conditions in India and elsewhere, and those field studies conducted under other conditions suggest the possibility of influencing the cognitive development of the learners. If cognitive development, which includes the development of logical reasoning and the construction of physical reality, is taken as the objective of teaching science, a thorough restructuring of the curriculum and executing it through a model of instruction which would induce cognitive conflict or dissonance in the learner might be of help.

3.4.1 Reorganising the curriculum frame.

Ausebel (1963) argues that 'any science curriculum worthy of the name must be concerned with the systematic presentation of an organised body of knowledge as an explicit end in itself'. There are many other educationists who would tend to agree with him. Such a systematic presentation of the body of knowledge may not by itself be able to produce any effect in the construction of logico-mathematical structures and concept structures by the learners. The total reorganisation of the curriculum frame may have to be done in the light of 1) the previous concept structures of the learners and 2) the logical reasoning patterns they are capable of manifesting. This manifestation depends on the

logico-mathematical structure of the learners. This is one implication that can be derived from the empirical evidences discussed in the previous chapter (refer section 2.7). It becomes all the more meaningful in the Indian context because the students of a particular grade have undergone the treatment of a static and ill-prepared curriculum all through their previous years of schooling. It is ill-prepared from the point of view that any curriculum should have a theory base (Menon et. al. 1985). Menon (1985) on analysing the science curriculum of grades VIII to XII reports that such a theory base is lacking in the organisation of the science curriculum of the secondary and higher secondary stages. Looking at the problem of reorganising the curriculum frame from the theoretical framework on which the present study is based demands the assessment of the concept structures as well as the logico-mathematical structures of the learners. This can be further explained with an illustration. A curriculum frame in Chemistry, which deals with the structure and transformations of substances under stipulated conditions, demands the prior conceptual knowledge of the molecular nature of matter and their transformations can occur in certain patterns depending upon the physical conditions. If such a background knowledge is absent in the learner it has to be developed. The development of such concepts faces a serious hurdle if the learners are operating at a concrete

level. The concept that matter is made of discrete particles and these particles are capable of certain transformations depending on their structure, needs formal logic to assimilate. To concrete operational learners, perhaps, the best way to approach the problem is by concretising the data from which scientists themselves arrived at these concepts. The concretised data may be presented to the learner, after assessing his concept structures, in such a way as to arouse curiosity and create certain conflicts in the mind of the learners similar to those developed in the scientists who have constructed these laws, principles and theories. The assessment of the concept structures of the learner is important because that would reveal the internal contradictions and gaps in those structures which would form a major sourse of directive for the resequencing of data. Giving a historical perspective to the resequencing of the curriculum frame may be of relevance. But tracing the history of development of a concept through time may not be required in a classroom instruction. Historically, concepts might have evolved in a detour fashion after having entertained many alternative explanations to the phenomenon concerned and taking time to eliminate the incorrect explanations pending theoretical and methodological breakthroughs. Since learning is what may be called a rediscovery of the conceptual structure of science, most of

those detours could be bypassed while reorganising the curriculum frame to ensure the economy of instruction (Arunkumar et. al., 1984). Some of these detours may arise from the learner as he progressively constructs his cognitive structure. The facilitator (instructor) will have to be sensitive to accept these detours and not to 'ignore' them, and present the right type of data, from the historical development of the concept or artificially contrived ones, to make the learners realise the contradiction in those detours thereby aiding him in constructing stabler concept structures.

Another principle that can guide an attempt at reorganising the curriculum frame is that, the reorganisation should be done in consideration to the conceptual structure of the discipline. Shulman and Tamir (1973) quoting Schwab in their article on research on teaching say that 'the conceptual structure of a discipline determines what we shall seek the truth about and in what terms that truth shall be couched. The syntactical structure of a discipline is concerned with the operations that distinguish the true, the verified, and the warranted in that discipline from the unverified and unwarranted. Both these - the conceptual and the syntactical - are different in different disciplines'. Schwab clearly indicates how the conceptual structure of the

discipline determines what is to be taught. From the above discussion we can conclude that a curriculum reorganisation has to be carried out in considering the following: 1) the prior concept structure of the learners', 2) the logical reasoning patterns the learners are capable of manifesting based on their logico-mathematical structures, and 3) the conceptual structure of the discipline. Such a reorganisation of the curriculum frame should make it highly flexible and dynamic. The dynamism and flexibility of the curriculum frame may be seen in terms of its adaptability to the various cognitive demands of the learners, Such a dynamic curriculum frame should make it highly flexible and dynamic. The dynamism and flexibility of the curriculum frame may be seen in terms of its adaptability to the various cognitive demands of the learners. Such a dynamic curriculum frame may be successful in inducing cognitive conflicts in the learner by resolving which he constructs stabler cognitive structures.

3.4.2 A theory based model of instruction

The dynamism of such a curriculum frame would mostly be seen in the instructional model, the model being a part of the curriculum. So, the theory on which the instructional model is based will have to be the same as that on which the curriculum frame is based. The purpose of instruction, therefore, is construction of cognitive structures in the

learner isomorphous to the conceptual structure of the discipline. Though this idea seems to be more in tune with the Ausebelian subsumption theory of learning (Ausubel, 1968), it is very similar to Piaget's formulations regarding scheme of cognitive organisation which reflects his interests in the developing relations among the elements of knowledge (Shulman and Tamir, 1973). Hence, learning of science is not merely storing isolated bits of information concerning natural phenomena in memory, but progressively, constructing a wholistic, unified, and internally consistent understanding of the phenomena. For, such an evolution of wholistic structures in the learner necessitates the use of processes of scientific enquiry as a strategy. It is worthwhile, at this juncture, to note what Schwab (1962) has to say about classroom instruction as inquiry. "The phrase - the teaching of science as enquiry - is ambiguous. It means, first, a process of teaching and learning which is, itself an enquiry, 'teaching as enquiry'; second, instruction in which science is seen as a process of inquiry, 'science as enquiry'. The ambiguity is deliberate. Both these meanings are part of the idea in its complete form. The complete enquiry classroom would have two aspects. On the one hand, the student would be led to inquire into these materials. He would learn to identify their component parts, detect the relations among these parts, not the role played by each part, detect some

of the strengths and weaknesses of the inquiry under study. In short, the classroom would engage in an enquiry into enquiry."

The distinction between 'science as enquiry' and 'teaching-learning as enquiry' is an important one. In the second, it may be noted that the activity in which the student participates is not scientific enquiry per se, but, the critical analysis, interpretation and evaluation of reports of scientific enquiry. Therefore, a classroom interaction cannot be an uncontrolled free enquiry. Free enquiry or science as enquiry does not seem to aid the development of cognitive structures of those learners who operate at the concrete level (refer Chapter II, section 2.5). A guided enquiry approach where the teacher acts as a facilitator and guide to the process of enquiry would be better. It may be noted here that the facilitator and guide to the process of inquiry may provide data in such a way to the learners that the problem arises from within the learners rather than the facilitator giving prescriptive problems to the learners. These prescriptive problems may not appear as problems at all to the learners. A conceptual background is prepared by the teacher (facilitator) through discussion or through the provision of a concrete experience which culminates in the identification of a problem by the learners.

The teacher consciously creates the background of the problem keeping in view the total curriculum frame and the concept to be highlighted and also the level of abstraction which the stage of cognitive development of the learners' allows. In this given background the problem gets evolved as a hurdle in the way of the learners' explaining a certain phenomena. Confronted with the problem, the next step would be to call for alternative hypothetical solutions to it. Here the teacher's role would be mainly to act as a moderator and thereby see that every member of the class participates and a hypotheses, however apparently irrelevant it might be, is taken seriously. Concomitant to this, can be the logical exercise of eliminating internally contradictory propositions. Such an exercise should be done mostly by the fellow learners (peer interaction referred to in Chapter II, section 2.6). Those hypotheses which cannot be challenged through possible observations are not taken into consideration. They may be considered metaphysical propositions and not scientific questions. The next stage is essentially aimed at testing the hypotheses formulated in the earlier stage. The first step in the testing procedure is to deduce the hypothesis into possible observational events through which it can be tested for its validity. However, for the testing per se, a formal instructional situation has a lot of constraints regarding physical

resources and time. Ideally, what is desired and could be done wherever possible, is to fabricate procedures through which observations can be made regarding the validity of the hypothesis. Many a time, this may not be possible due to the nature of the hypothesis, nature of the concept, facilities required for making the necessary observations, the time it might take, etc. In such situations, there could be three other ways of putting the hypothesis to test. One is the recollection of common experiences of the learners and their proper organisation in such a way that these experiences provide evidence regarding the validity of the hypothesis. If the experiences called for are unfamiliar to the learners, the teacher may provide data derived from relevant experiments conducted by the scientists. A third way of testing would be to evolve through discussion certain observations that could be made by the learners at home or through a project/assignment involving field observations. In all the above four ways of testing what is of paramount importance is that the learners actively participate in the planning and fabrication of the testing procedures making direct observations wherever possible and interpret and formulate conclusions from observations made or data provided. Hypothetical solutions to the problem having been tested would be meaningfully integrated to the cognitive structures.

Also, these empirical evidences arouse further problems for investigation. Thus, the whole process of instruction is cyclic in nature (Arunkumar et. al., 1984).

3.5 The Effect of Curriculum Experiences on the Reasoning Patterns

The organisation of the curriculum frame on those lines discussed earlier and executing it through the cyclic model of instruction described above is likely to aid the construction of stabler cognitive structures by the learners. This would include the construction of both the concept structures (knowledge of the physical world) as well as the logico-mathematical structures. The above statements are made based on two reasons. One, the concretisation of formal concepts can be better assimilated into the cognitive structures of the concrete-operational learners. Several such assimilations of concretised data would demand the structures to undergo modifications. This need arises from within the learners. Two, the dynamic curriculum frame is capable of adapting to the cognitive needs of the learners' and inducing cognitive dissonance in them. The resolution of these cognitive conflicts would aid the construction of stabler structures.

In the intellectual development model propounded by Piaget, mental operations appear during the third stage,

i.e., the concrete operational stage. Piaget (1964) says 'when learners discover the properties of their actions, they have begun to perform mental operations. An operation obviously is reversible and is an interiorised action'. An early concrete operational child may need a long term interaction with the environment to transform to the formal operational stage. Also, the early concrete operational child may not benefit out of instruction of formal concepts, though it may be presented in a concrete form, as he is not equipped with a structure that enables him to assimilate such concepts. Therefore, it may be worthwhile to attempt at influencing the cognitive development of learners when they are in a transition from concrete to formal operational stage. This is more relevant from an experimentation point of view because the time duration that can be spared for the experiment is limited. Kimball (1973) discusses the following points in answering the question whether formal operations can be induced. 'The individual that is to be introduced to the formal operations must be facile with the concrete operations; able and experienced in manipulating materials; capable of formulating generalisations; identifies variables and exhibits reversibility'. The above discussion by Kimball clearly indicates that an attempt at accelerating the reasoning patterns may be carried out with fully concrete operational learners and not with early concrete operational learners.

Most of the acceleration studies reviewed in Chapter II have been carried out with transitional learners.

3.6 A Transitional Group in the Secondary School System

Tha age range suggested by Piaget, following the data collected from Genevan children, may not be of use in identifying a transition group in Indian conditions because cross cultural studies carried out elsewhere by several researchers indicate wide variations from the Genevan norms (Chiappetta, 1970; and Dasen, 1974). In India there is no study which reports the distribution of concrete and formal operational students in the secondary school system. Vaidya (1974) indicates that more than 70% of pupils of grade X could not test hypotheses. Chand (1980) reports after studying the mental operations of 240 boys and 240 girls between the age range of 4+ and 15+, that even students of age 16 does not operate at the formal operational level. These studies do not suggest a transition group. Therefore, a bench mark data was collected from the field. The sample included students from grade VII, VIII, IX and X. The data was collected from three English medium schools in Baroda city. The 'colour chemical task' (Piaget and Inhelder, 1958 Pp.107-122) was used to probe into the reasoning pattern of the students (See Appendix B). A clinical interview technique was used to assess the logical reasoning (the

clinical interview technique is discussed in detail in the next chapter on procedural details, as a discussion here is unwarranted). The results of the interviews after analysis were classified into four categories of reasoning patterns viz., concrete operational (II A); transitional (II B); early formal (III A) and formal operational (III B). The protocol developed by Renner et. al. (1976) was used for this classification. The number of pupils interviewed, the number of transitional students (II B) and the percentage of transitional students is presented in Table 3.1.

Table 3.1
The percentage of students who show signs of transition from concrete to formal reasoning

Grade	VII	VIII	IX	X
tran.	3	6	26	12
N	38	25	48	22
%	7.7	20	54.3	54.5

3.6.1 Reasoning Patterns That Differentiate Concrete and Formal Operations.

Another question that comes in alongwith the selection of a grade having students belonging to a transitional group is the one regarding the discrimination between the concrete and formal operational students from an assessment point of

view. The formal reasoning is a complex structure and so its assessment is a complicated job. To describe the level of reasoning of individual students, and to assess their cognitive capabilities, the notion of reasoning pattern is more useful than the composite operational structure. Karplus (1979) says, a reasoning pattern, such as seriation, controlling variables, conservation, is an identifiable and reproducible thought process. Reasoning patterns have underlying logical and logico-mathematical operations proposed by Piaget. Some of these operations appear to be fairly easily identifiable in a student's words and actions, while others require detailed observation and analysis. By contrast, reasoning patterns are better evident when a student is confronted with a problem and in the way he goes about solving it. A few examples of reasoning patterns that occur while a student is confronted with a problem are: 1) combinatorial reasoning, 2) controlling of variables, 3) deductive reasoning, 4) proportional reasoning and 5) serial ordering. These reasoning patterns are interrelated - some of them closely while some others are relatively a little remotely. The reasoning patterns all together form the logico-mathematical structure and the closely related patterns form 'schema' within this total structure. Different schemata interact among themselves and evolve from lower states of equilibrium to higher ones (See chapter I, section

1.2.1). Some of these schema evolve to a higher level compared to others. Such differences in the levels of evolution of schema is termed as 'décalage' in the Piagetian theoretical framework. Therefore for an experimental purpose it would be better to choose closely related schema especially from an assessment point of view, to represent the total logico-mathematical structure. From the examples of reasoning patterns given above combinatorial reasoning and controlling of variables are closely related. These two reasoning patterns have been used by other researchers in attempting at developing the formal operational thought. A few among them are Kuhn and Angelev, (1975); Karplus, (1978); Woolman & Chen, (1982); and Lawson et. al., (1975). Lawson (1979) says "In Piaget's theory, formal stage reasoning manifest itself in a variety of ways. For example, the generation of all possible combinations of variables, the isolation and control of variables, and the solution of proportionality, all theoretically require formal operations. Although these abilities may appear to be unrelated, in theory they are all mediated by the development of a structural unit of an unified whole. Thus, according to theory, individuals should exhibit consistency in performance across tasks that require these operations. The evidence for this consistency, however is inconclusive" (p.67). Though Lawson mentions that the relationship among the three reasoning patterns is

inconclusive, the generation of all possible combination of variables and the 'isolation' and 'control' of variables appear to be more relatively connected because 'generation' of all possible combinations is required for 'isolating' and 'controlling' variables. Therefore, the assessment of concrete and formal operations in students may be done using tasks or problems which demand the children to manifest their combinatorial reasoning (generation of all possible combinations), and to isolate and control variables in a multivariate situation. Thus, 'combinatorial reasoning' and 'controlling of variables' form a part of the 'combinatorial system', which forms a major part of the formal logic.

The discussions in the two preceeding sections indicate the choice of grade in the secondary school system for the present attempt at influencing the cognitive development and the choice of reasoning patterns in order to assess the logico-mathematical operations of the students. Summarising the discussions from sections 3.4, 3.5 and 3.6 the research question of the present study boils down to whether the reorganising of the curriculum frame as discussed earlier would aid the development of reasoning patterns of the transitional group of students under actual classroom conditions. That is, an active participation by the students on the curriculum material presented to them is required for

the acceleration of the reasoning patterns. In an actual classroom there may be many students who are basically not interested in the instructional activities. These students would pose a major hurdle in seeking an answer to the above discussed research question.

3.7 Title of the Present Investigation

A STUDY OF THE EFFECT OF REORGANISING THE PRESCRIBED CURRICULAR FRAMEWORK ON THE COMBINATORIAL REASONING AND CONTROLLING OF VARIABLES OF GRADE IX STUDENTS.

3.7.1 Expansion of terms

(a) reorganising: The reorganisation of the curriculum frame is done after taking into consideration 1) the background knowledge of the learners 2) their logico-mathematical structures and 3) the conceptual structure of the discipline. As the knowledge of the physical reality and their reasoning abilities develop, the curriculum frame should get modified to suit the growing cognitive capabilities of the students. Therefore, the reorganising is dynamic and flexible in contrast to a 'reorganised' curriculum frame which would be static and rigid.

(b) curriculum frame: The curriculum frame in the present

study refers to the chemistry portion of the prescribed science curriculum frame for the grade IX of the Gujarat Board of Secondary Education.

(c) combinatorial reasoning: This is a reasoning pattern manifested by a student when posed with a problem that requires the generation of all possible combinations pertinent to the solution of the problem.

(d) controlling of variables: Recognising the necessity of an experimental design that controls all variables except the one being investigated.

3.8 Scope and Limitations of the Study

The study is aimed at accelerating the logical reasoning of students with the aid of curricular experiences in a real classroom setting, with all its natural interferences. To this extent it is not a laboratory type of experimentation where the variables are controlled. The assumption here is that the students will actively participate in the classroom interaction so that their reasoning patterns develop. But, within the limited period of time that can be spared for a Ph.D. work it may not be possible to get all the individuals of a classroom motivated to take part cognitively in the interaction process. This task becomes all the more difficult when the instructor and

learners are 'new' to each other. There are several other factors which contribute to making this task difficult viz., the social and economic background of the learners, their interests and aptitudes. Thus, the experiment is an attempt at accelerating the reasoning patterns of students in an actual classroom setting with not much of an effort made to control the umpteen intervening variables. The experimentation is for a short period to expect total developmental changes in the cognitive structures. Given these restrictions the study aims at finding out how far the reorganising of the curriculum frame can accelerate the logical reasoning of students in the present school set up.

3.9 Objectives of the Study

The objectives of the study can be stated as follows:

1. To assess the level of reasoning of students of grade IX in the following reasoning patterns
   (a) combinatorial reasoning and (b) controlling of variables.

2. To analyse the chemistry portion of the science curriculum of grade IX with a view to reorganising it to suit the level of reasonong of the students.

3. To study the effect of reorganising the curriculum frame on the following reasoning patterns

(a) combinatorial reasoning and (b) controlling of variables in comparison with the existing curriculum frame.

The assessment of the level of reasoning (objective No.1) demands the use of problems or tasks to be presented to the students and observing the way they go about solving it. The exposure to such problems or tasks might interfere with studying the effect of the treatment (objective No.3). Here arises the need to study the effect of the pre-assessment and its influence on the treatment. Therefore, the following two objectives are added alongwith the above three.

4. To study the effect of assessment of the reasoning patterns, (a) combinatorial reasoning and (b) controlling of variables on the development of the same reasoning patterns.
5. To study the interaction between the pre-assessment and treatment on the two reasoning patterns viz., (a) combinatorial reasoning and (b) controlling of variables.

3.10 Hypotheses of the Study

An analysis of the objectives of the study in the

background of the theoretical framework and the empirical evidences and taking into consideration the field conditions in India, the following hypotheses are formulated.

1. The reorganising of the chemistry portion of the science curriculum for grade IX may positively influence the combinatorial reasoning of students when compared to those students who undergo the normal classroom teaching based on the existing curriculum frame.

2. The reorganisation of the chemistry portion of the science curriculum for grade IX may positively influence the 'controlling of variables' of students when compared to those who undergo the normal classroom teaching based on the existing curriculum frame.

The above two hypotheses have been framed in the directional form since earlier attempts show that acceleration is possible.

The objective 1 demands the assessment of the reasoning patterns of the students before attempting at reorganising the curriculum frame. This is done by posing problems to the students which demand them to manifest these different reasoning patterns. Such a pre-assessment may affect the

development of these reasoning patterns. Among the studies where such a test sensitivity has been measured, Rowell and Dawson (1981) report that pretest has influenced the Volume conservation of grade VIII students in a classroom acceleration experiment. But, they add that the influence of the pretest was only to a small extent. This is not convincing enough to formulate the following hypotheses in the directional form and therefore, they have been expressed in the null form.

3. There is no difference in the combinatorial reasoning of students, who have been assessed through a task or tasks which demand(s) the use of such a reasoning pattern, and those who have not been assessed through such a task or tasks.

4. There is no difference in the 'controlling of variables' of students, who have been assessed through a task or tasks which demand the use of such a reasoning pattern, and those who have not been assessed through such a task or tasks.

The above two sets of hypotheses indicate that there are two possible sources of influences on the reasoning patterns viz., the pre-assessment and the treatment. In such a situation in addition to the possible individual influences there can be a joint effect of the two influences acting

together (objective No.5). This objective calls for the formulation of two more hypotheses.

5. There is no difference in the 'combinatorial reasoning' of students, who have been pre-assessed on the same reasoning pattern and who have undergone the treatment (the reorganising of the science curriculum), and who have not been pre-assessed and not undergone the treatment; and those who have not been pre-assessed and who have undergone treatment, and those who have been pre-assessed but not undergone the treatment.

6. There is no difference in the 'controlling of variables' of students, who have been pre-assessed on the same reasoning and who have undergone the treatment, and who have not been pre-assessed and not undergone the treatment; and those who have not been pre-assessed and who have undergone treatment, and those who have been pre-assessed but not undergone the treatment.

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CHAPTER IV

PROCEDURAL DETAILS

4.0 Introduction

The procedure adopted to realise the objectives set and test the hypotheses formulated, is described in this chapter. This is carried out under four main heads viz., design, sample, tools and techniques, and the experiment. From the discussions in the previous chapter; on the scope and limitations of the study, the objectives, and the hypotheses, it is clear that the present investigation aims at studying the effect of reorganising the prescribed curricular framework on the reasoning pattern of grade IX students. Also, it is indicated that this effect is studied in comparison to the natural development and the effect of the prescribed curriculum frame. The design of the study has to accommodate the above comparison, the question of the influence of pre-assessment on the development of reasoning, and the interaction of treatment and pre-assessment. The pre-assessment as well as the assessment after treatment have to be done by posing problematic situation to each student and making observations on how he goes about finding a solution to the problem. Such an assessment demands the use of planned problems or tasks and the use of

clinical interview technique. These are discussed in detail in the sections to follow.

4.1 The Design of The Study

The design should be able to accommodate the study of the following: 1) the effect of reorganising the prescribed curriculum frame on the reasoning pattern in comparison to the existing (prescribed) curriculum frame, 2) the effect of pre-assessment on the development of these reasoning patterns and 3) the interaction between the treatment and the pre-assessment. Mitzel (1982, p.627) says that 'as the complexity of the research question increases, the complexity of the design necessary to answer the question increases as well'. He continues to say that 'in some instances the researcher may suspect that the presence of pretest affected the outcome variable or that the pretest interacted with the treatment to produce different results. The issue may be examined through what is called a Solomon Four Group Design'. Campbell and Stanley (1963 and 1971) say that the Solomon Four Group Design desrvedly has higher prestige compared to other pretest - posttest designs and control and experimental group designs and represent the first explicit consideration for external validity factors. Dayton (1970, p.156) says as follows: "The Solomon Four Group Design is an experimental design especially

constructed to provide control for sensitisation efforts in personality-change experiments. The design enables one to control and measure both main and interaction effects of testing and the main effects of a composite of maturation and history". It has become the new ideal design for social scientists says Campbell (1969). Borg and Gall (1983) say that "the Solomon Four Group Design is used to achieve three purposes: 1) to assess the effect of the experimental treatment relative to the control treatment; 2) to assess the effect of a pretest; and 3) to assess the interaction between pretest and treatment conditions" (p.691). About the effect of pretest they say as follows: "The pretest might have an effect on student achievement or attitudes because it provides an opportunity to 'practice' or think about the content incorporated in the pretest. Also, the pretest might have a special effect on the experimental group students because it 'sensitises' them to study specific content incorporated in the experimental treatment. The pretest would not have this effect on the control group because, by definition, they are not exposed to the experimental treatment content" (p.692).

The design is as follows:

Group 1	R	O_1	X	O_2
Group 2	R	O_3		O_4
Group 3	R		X	O_5
Group 4	R			O_6

where R is random assignment, X is experimental treatment and O_1 to O_6 are observations. The effect of the treatment (X) can be studied in four different ways viz., 1) O_2 O_1; 2) O2 O_4; 3) O_5 O_6 and O_5 O_3. The actual instabilities of experimentation are such that if these comparisons are in agreement, the strength of the influence is greatly increased (Campbell and Stanley, 1971 p.195). If the pretest provides a practice effect, this should result in higher post test performance by groups receiving the pretest (1 and 2), than by groups not receiving the pretest (3 and 4). If the pretest sensitizes the experimental group to study specific content, this should result in a pretest - treatment interaction. Specifically, there should be greater difference on the posttest between groups 1 and 3 than between groups 2 and 4. This is because a sensitisation effect means that the pretest facilitates the learning of the experimental group but not the control group (Borg and Gall, 1983 p.692). Disregarding the pretests, the posttest scores can be treated with a simple 2X2 analysis of variance design:

	Treatment	No Treatment
Pretested	O_2	O_4
Not Pretested	O_5	O_6

From the column means, one can estimate the main effect of the treatment, from row means, the main effect of pretesting

and from cell means, the interaction of testing with treatment.

4.1.1 Adaptations of the design for the present study

One of the assumptions of the Solomon Four Group Design is the randomisation of the subjects in the four groups. Randomisation in the present study is not carried out by pooling all the units of the sample and alloting them to the four groups; but, four clusters are taken from an institution which does not have any specific criteria for the allotment of students into each division. Also, the equivalence of the four groups is established on two external criteria viz., 1) age and 2) non verbal reasoning as measured through Raven's Standard Progressive Matrices. This is one of the adaptations of the design to the present study. This was done because the natural setting was not to be disturbed. An artificial reallocation of the units might alter the natural setting.

Another assumption of the design is that the four groups are allocated at random to Group 1, Group 2, Group 3, and Group 4 as shown in the design (given in section 4.1). In the present investigation the two experimental groups (Group 1 and Group 3, as given in the design) belong to the academic year 1981-'82 and the two control groups (Group 2 Group 4) to the year 1982-'83. Such an adaptation was done

because of two reasons. One, the non availability of four equivalent groups from one institution. The institution has to be same, to which all the four groups belong, because the physical and social setting of different schools may differ. Also, there may be slight variations in the instructional modes (of the control groups) in different institutions. Two, the possibility of interactions among the experimental and control group students which might influence the findings, especially because the treatment prolonged for one full semester (six months). Therefore, the two groups (IX A and B divisions) of the academic year 1981-'82 were treated as experimental groups (Group 1 and Group 3 of the design); and the two groups of the subsequent year as control groups (Group 2 and Group 4 of the design).

4.2 Sample of the Study

The sample of the study comprises of four groups of students of students of grade IX of an English medium school in Baroda. Two of the groups belong to the academic year 1981-'82 and the other two of the academic year 1982-'83. The distribution of students in the four groups is given in table 4.1.

A large majority of the students in the sample are Gujaratis i.e. 90.2% of the total sample. They speak Gujarati

Table 4.1

The Distribution of the Sample of the Study

Academic year	Grade & division	Boys	Girls	N	Position in the design
1981-82.	IX A	37	13	50	Group 1
1982-83.	IX A	39	13	52	Group 2
1981-82.	IX B	26	26	52	Group 3
1982-83.	IX B	30	20	50	Group 4

at home and with peers they speak either in Gujarati or Hindi. Only 6% of the students speak English at home. The parantal occupation of 124 students, out of 184 Gujarati students, is business ranging from small shops to industries. Among the non Gujarati students only two out of twenty are doing business. The above given information is based on data collected alongwith the clinical interviews discussed in detail in the coming sections. The break up of the number of students in these groups is given in table 4.2.

Table 4.2

The distribution of parantal occupation and language spoken at home in the four groups of the sample.

	N	Parantal occupation		Language spoken	
		Business	Service	English	Indian
Group 1	50	30	20	5	45
Group 2	52	31	21	1	51
Group 3	52	33	19	3	49
Group 4	50	32	18	3	47

The institutions to which these four groups of students belong does not show any bias in allotting students to different groups. That is, no special criteria is employed while allotting students to the different divisions of a grade during admissions[1]. Therefore, the allocation of units in the four groups may be taken as quasi-random allocation although, no reallocation, after pooling all the units, has been attempted. As discussed in the previous section the equality of the four groups is established on two external criteria viz., age and intelligence as measured through Ravens Standard Progressive Matrices (RPM). The age of the students was collected from the school records and the intelligence was measured using the standardised group test. One-way analysis of variance was carried on the two sets of data viz., age and intelligence (raw scores as obtained through RPM). The age and raw scores of the test alongwith the details of calculation are given in Appendix A. The summary of the analysis of variance is given in the tables 4.3 and 4.4 (Garret, 1966 Pp.280-284).

Table 4.3

Summary of Analysis of Variance on the Age of the four groups of students (sample).

Source of variance	df	Sum of squares	Mean square	F	Signif-cance
Between	3	2.75	0.91		Not sig-nificant.
Within	200	142.35	0.71	1.28	
Total	203	145.1			

Table 4.4
Summary of Analysis of Variance on the raw scores (RPM) of the four groups of students

Source of variance	df	Sum of squares	Mean square	F	Significance.
Between	3	376.95	125.65		not significant.
Within	200	19938.05	99.69	1.26	
Total	203	20315.00			

The above two tables show that the two F values are not significant. Therefore, the distribution of age and intelligence of the units in the four groups are equal since the mean differences are not significant.

4.3 Tools and Techniques of data Collection

The tools used in the present study are discussed hereunder according to the nature of data obtained from them and the techniques used to collect the data. They are discussed under four sections viz., 1) clinical interview 2) observation schedule and 3) unstructured interview. The clinical interview technique is used to assess the logical reasoning of students, the observation schedule is used to describe the classroom instruction of the experimental and control groups, unstructured interview technique is used to study the bases for the interest or lack of it in the instructional process of students (especially of the experimental groups).

4.3.1 Clinical interview

Objective No. 1 of the study demands the assessment of two reasoning patterns viz., combinatorial reasoning and controlling of variables. There are three possibilities of assessing these reasoning patterns i.e., testing, pure observation and clinical interview. The merits and demerits of each of these are discussed below to highlight the meed for a clinical approach in assessing reasoning patterns.

A paper-pencil test or any other form of testing; that is to say, the method of posing questions so arranged as to satisfy the two following requirements: first, that the question and the conditions in which it is submitted remain the same for each student; second, that each answer be related to a scale or schedule which serves as a standard of comparison both qualitative and quantitative, has certain disadvantages. The disadvantages of this method are indisputable in diagnosing children individually. Firstly, it does not allow a sufficient analysis to the results. When working under the stereotyped conditions which the test method demands only rough results can be obtained, which, though interesting in practice, are too often less of use as theory, owing to the lack of context. In short, the test method has its uses, but for the present problem it tends to falsify the perspective by diverting the student from his

natural inclination. It tends to neglect the spontaneous interests and primitive reactions of the student.

The question of pure observation arises next. In the case of present research it is the observation of the spontaneous questions or reactions of students' which furnishes data of importance. The detailed study of these questions or reactions reveals the questions which is revolving in the student's mind and thus reveals his cognitive structure. But, the direct observation method has drawbacks also. It is very tedious and is unable to guarantee the quality of the results, except at the cost of their quantity (it is, in fact, impossible to observe a large number of students under similar conditions). In addition to the above drawback, the pure observation has two systematic defects. First, the student's intellectual egocentricity constitutes a serious obstacle to knowing him by pure observation unaided by questions. The student neither spontaneously seeks nor is able to communicate the whole of his thought (Piaget, 1926 chapters I & II). The second drawback to the method of pure observation is the difficulty of distinguishing a student's play from his beliefs. It is essential to go beyond the method of pure observation and without falling into the pitfalls of the test method, to take full advantage of what may be gained

from the experiment. With this in view a third method is used which claims to unite what is most expedient in the methods of test and direct observation, while avoiding their respective disadvantages: this is the method of clinical examination, used by psychiatrists as a means of diagnosis. Cowan (1978) says that the procedure adopted in a clinical interview is designed to uncover students' thinking and reasoning abilities. The correctness or incorrectness of the answers presented by the student is important as it provides the interviewer with information about the quality of the students' thought processes (Wadsworth, 1978 p.225). Wadsworth defines the clinical interview as an ongoing experimental process in which "the interviewer asks questions to a child, listens, observes, makes a hypothesis about the child's conceptual ability, and proceeds to ask more questions based on the hypothesis he has formed". The interviewer uses probing questions to get at underlying reasoning, provides conflict situations, makes counter suggestions, encourages the child to test predictions and verify answers, suggests helpful strategies, and shifts to related tasks to verify understanding (Cowan, 1978). The interview is not a fixed set of questions but rather a set of skills to be used during a dynamic exchange between teacher and student. Posner and William (1982) say that

'the clinical interview has an information - gathering function. Its chief goal is to ascertain the nature and extent of an individual's knowledge about a particular domain by identifying the relevant conceptions he or she holds and the perceived relationship among those conceptions. Once obtained, this information could be represented in a suitable format, such as a semantic network, which would be equivalent to a partial representation of the individual's cognitive structure. This approach was pioneered by Jean Piaget who in the 1920's developed what he termed as a "clinical method" for investigating the nature and extent of childrens' knowledge' (p.195).

The interview begins with the establishment of rapport between the interviewer and interviewee. The interviewer makes sure that the interviewee has perceived the problem as he wants him/her to, by continually asking questions on his/her understanding of the problem. That is, rather, a difficult task for the interviewer, especially when the language in which he communicates comes in the way of the way of the interviewees understanding. One way of tackling such a problem is by asking the interviewee to describe the physical details of the task presented in his/her language and use the same words which he/she uses in asking further questions during the clinical interview.

'the clinical interview has an information - gathering function. Its chief goal is to ascertain the nature and extent of an individual's knowledge about a particular domain by identifying the relevant conceptions he or she holds and the perceived relationship among those conceptions. Once obtained, this information could be represented in a suitable format, such as a semantic network, which would be equivalent to a partial representation of the individual's cognitive structure. This approach was pioneered by Jean Piaget who in the 1920's developed what he termed as a "clinical method" for investigating the nature and extent of childrens' knowledge' (p.195).

The interview begins with the establishment of rapport between the interviewer and interviewee. The interviewer makes sure that the interviewee has perceived the problem as he wants him/her to, by continually asking questions on his/her understanding of the problem. That is, rather, a difficult task for the interviewer, especially when the language in which he communicates comes in the way of the way of the interviewees understanding. One way of tackling such a problem is by asking the interviewee to describe the physical details of the task presented in his/her language and use the same words which he/she uses in asking further questions during the clinical interview.

While the problem is presented to the interviewee the interviewer sets several hypotheses on the responses of the interviewee. These hypotheses are tested against the actual responses of the interviewee which are stimulated. Piaget (1960) has classified the reactions of an individual, who is being clinically being examined into five categories. They are: 1) answering at random with total disinterest on the posed problem; 2) romancing: i.e., inventing an answer which he really does not believe; 3) suggested convictions: i.e., answers based on suggestions in the questions; 4) liberated convictions: i.e., answers which comes out of the mind as though it is getting liberated and 5) spontaneous convictions: i.e., answering from a previous original reflection. Among the five types of responses, the first three do not help the interviewer much in understanding the cognitive structures of the student. The last two are best suited and the 'liberated conviction' is the best between the two, from the point of view of understanding the interviewees cognitive structures. An interviewer has to be extremely cautious and sensitive in order to properly understand the responses. The interviewer has to take the whole context of the situation into consideration before judging a reaction and not analyse the responses in isolation for its merits as to find whether the response is

'right' or 'wrong'. The advantage of this technique over others is that during the presentation of a problem it can be ensured by the interviewer that it has been conceived properly. Also, wherever clarifications, are needed on the interviewees reaction, can be sought immediately by the interviewer. This would enable the interviewer in making valid judgements on the reactions of the interviewee. The disadvantage is that it is time consuming and tedious.

In order to assess the reasoning ability of children with the above mentioned technique needs carefully planned tasks or problems to be presented to the students for them to react upon. The present study is an attempt at accelerating two reasoning patterns viz., combinatorial reasoning and controlling of variables. In order to assess each of these reasoning patterns at least two tasks may be required. The assessment using one task may be risky from a scientific point of view since it may give rise to erroneous conclusions. In order to increase the validity of the information at least two tasks would be required and a correlation of the assessment between the two tasks may indicate this. Therefore, four tasks will be required to assess the two reasoning patterns. The design of the study, as given in the earlier part of this chapter (section 4.1), clearly indicates that the observations O_1 and O_2 are made

on the same students. Similarly observations O_3 and O_4 are made on another group of students. Since, there are two sets of repeated measures parallel tasks are required. The use of parallel tasks would reduce the carry-over effect to a minimum when compared to using the same task. That is, the pre-assessment may induce students to reason in a particular way or initiate certain thought patterns in them which might influence the post-assessment. Familiarity with the tasks might also make the students perform better when they are used on a repeated assessment using the same task. Therefore, it can be concluded that four tasks each for assessing the reasoning pattern are required making a total of eight.

4.3.1.1 The tasks to assess the reasoning patterns

Inhelder and Piaget (1958) describe several tasks and clinical interviews through which these tasks are used to understand the cognitive structures of a multiple cross section of children and thus trace the stagewise evolution of cognitive structures. The purpose of using these tasks by Piaget was to study the construction of formal operational structures by children. The construction of these structures is described in three main stages viz., 1) the preoperational stage (Stage I), 2) the concrete operational stage (Stage II), and 3) the formal operational stage (Stage III). In their qualitative descriptions of these stages they divide the

latter two main stages comprising of two substages each. These substages are: 1) early concrete operational substage (II A), 2) concrete operational substage (II B), 3) early formal operational substage (III A), and 4) formal operational substage (III B). Though Piaget has used the tasks to study the construction of formal structures by adolescent children, several researchers have used these tasks for assessing the stage or substage of development of an individual child through the clinical interview technique (Renner et. al., 1976; Lawson, 1979; Dale, 1970; and Lawson 1975). Renner et. al. have developed a detailed protocol for assessing and classifying the reactions of children into the four groups or substages as discussed above. Inhelder and Piaget describe the use of about fourteen tasks of which three tasks are used in the present study. They are: 1) Combination of coloured and colourless chemical bodies, 2) Pendulum task, and 3) Falling bodies on an inclined plane. The first one is used to assess the combinatorial reasoning of students and the other two for assessing the ability to control variables.

There are several other researchers who have developed similar tasks for assessing the logical reasoning patterns. Among them a few are: 1) Lawson, (1978); 2) Lawson and Wollman (1976); 3) Frederman, (1974); and Wright, (1979). A review

of these research reports reveal that the responses to several tasks by the students are influenced by cultural factors. A selected few of these tasks when presented to a few adolescent children failed to extract 'liberated convictions' and 'spontaneous convictions'. Therefore, it was decided to develop, through continuous try outs, five other tasks. The five other tasks thus developed are: 1) Fun House Puzzle, 2) Hockey Player Puzzle, 3) Electrical Switching System, 4) Photosynthesis Puzzle and 5) Rate of growth of plants problem. Among these five tasks, task 1 'fun house puzzle'; task 4 'photosynthesis puzzle'; and task 5 'rate of growth of plants' are based on tasks developed by Walker et. al. (1979), Wright (1979), and Menon (1985) respectively. Task 2 and task 3 are developed by the investigator. Of these the first three tasks are designed to assess the level of combinatorial reasoning and the latter two are designed to assess the controlling of variables. Thus, eight tasks are used in the present study, four each for assessing combinatorial reasoning and controlling of variables. A short description of these eight tasks are given below. Detailed descriptions are given in Appendix E, alongwith the criteria for assessment.

i Fun house puzzle: The interviewee is given a plan of a three room house one connected to the other in a series

with several doors. With an active interaction a path is shown to the student through the three rooms. They are then asked to show, write or tell the total number of such possible paths.

ii Coloured chemicals: The student is presented with five colourless bottles marked 1, 2, 3, 4 and G, containing different colourless liquids. He is shown a test tube containing a colourless liquid taken from the bottles singly or in combinations and to it added 'G'. The colour changes to yellow. The child on observing this is asked to try as many times as he wants and produce the colour using spare tubes.

The above described tasks are used to assess the combinatorial reasoning of students.

iii Photosynthesis: A detailed description of an experiment to find the rate of absorbtion of carbon dioxide by different parts of plants are given to the student and asked a series of questions.

iv Pendulum: The student is supplied with threads of different length and bobs of different sizes and mass. They are asked to find out the variable which affects the period of oscillation.

The above described two tasks are used to assess the 'controlling of variables' of students.

v Hockey player puzzle: The interviewee is supplied with a card on which a hockey player is drawn. Alongwith this he is also supplied with coloured paper cuttings cut in the shape of a jersey, shots, stockings and boots. Jerseys of four different colour, shots of three different colours, stockings of two different colours and boots of two colours are supplied to the interviewee. The student is then asked to find the total number of possible combinations in which the playing gear can be worn.

vi Electrical switching system: This consists of a series of five switches numbered 1, 2, 3, 4 and the last switch marked 'M'. A combination of the switches 1, 2, 3, 4 in 'on' position and 'M' in 'on' position makes a light emitting diode glow as the circuit is complete. The interviewee is then asked to try all possible combinations of the switches in 'on' position to make the light emitting diode glow. The interviewee is encouraged to try all possible combinations even after striking one combination.

The above described two tasks are used to assess the 'combinatorial reasoning' of students.

vii Growth rate of plants: The student is supplied with data regarding the growth of six potted plants. They are asked to compare the six pots to answer a question regarding the comparative growth rate under similar conditions.

viii Falling bodies on an inclined plane: The student is supplied with an inclined plane. He is allowed to vary the angle of inclination. The interviewee is given a set of metal bobs of varying sizes and weights. The interviewee is asked to find the variable responsible for the length of bounce of the bob by performing experiments.

The above described two tasks are used to assess the 'controlling of variables' of the students.

4.3.1.2 Try out and validation of the tasks

All the eight tasks described above were tried out on twentyfour IX grade students of an English medium school in Baroda. The try out sample consisted of ten girls and fourteen boys. Their age varied from twelve years and four months to fifteen years and nine months. Their average age is thirteen years and seven months. Each student was called on to a room free from disturbances and a task was presented to him/her (interviewee) by the investigator (interviewer).

Before presenting a task the investigator (interviewer) explains the purpose of the interview. Special emphasis is given to indicate that the tasks they are going to do is not a 'test' or 'examination'. This is done to reduce the 'test anxiety' of the interviewee. Alongwith this the interviewer asks questions regarding their study habits, from whom they seek help for their academic problems, their position among the siblings, etc., to establish rapport with the interviewee. Such questions asked in an informal situation gives the interviewer an insight into his interest in the curricular activities. After establishing rapport with the interviewee a task is presented to him/her ensuring clarity at each step of presenting the task. That is, after describing the task to the interviewee, the interviewer asks the interviewee to explain it in his/her own words. This helps the interviewer in identifying the hurdles of the interviewee in understanding the given problem. Care is taken by the interviewer in subsequent explanations to the interviewee to use the same words used by the latter. Detailed observations are made on how the interviewee goes about solving the problem. An audio recorder is used to record the conservation between the interviewee and interviewer. Thus two sets of observations are made viz., the interviewer's detailed recordings on the performance of the interviewee and the audio recording of the

conversation between the interviewer and interviewee. Both these recordings are then given to three judges who agree with the theoretical framework on which these observations are made and are familiar with assessing the reasoning of children using similar tasks, the invesigator being one among the three judges. The three judges were requested to assess the level of reasoning of each student. Directions were given to the three judges for assessing the reasoning patterns. The directions include the criteria for assessing the logical reasoning i.e., the reasoning patterns into four categories viz., early concrete (II A), concrete operational and showing signs of transition from concrete to formal (II B), early formal operational (III A), and formal operational (III B). The criteria were developed on the same lines as given in the protocol designed by Renner et. al. (1976). The criteria for assessment is given with each task in Appendix B.

The ratings of the three judges on the reasoning patterns (in all the eight tasks) of the twentyfour students are given in Appendix C. On a single task there can be thirtysix possible ways of disagreements among the ratings of the three judges on one student. Since there are twenty four students and eight tasks the total possible disagreements are: 36 X 8 X 24 = 6912. Out of these many possible disagreements among the judges, they have disagreed only

forty times (See Appendix C), thus making only 0.57% of the total possible disagreements. This shows the high reliability of the assessment procedure. It may also be noted from Appendix C that out of forty disagreements, there is not even a single case where the three judges have assessed a student's reasoning into three different categories. An example of such a pattern of assessment is as follows: judge A assesses a student's reasoning on a given task as II A; judge B as II B and judge S as III A. Another observation that can be made on the assessment is that the difference between the assessment of two judges on a given task and student is only of one degree. That is, the disagreement is only between two adjacent categories and not between far away ones. Out of the forty disagreements, thirty four are between the categories II A and II B and six between the categories II B and III A. All these indicate the high reliability of the procedure adopted to assess the reasoning patterns using the clinical interview technique with the aid of the tasks developed.

4.3.1.3 Relationship among the tasks assessing similar reasoning patterns

To establish the relationship among tasks assessing similar reasoning patterns, viz., combinatorial reasoning and controlling of variables, the judgements of one among the three judges is pooled together (See Appendix C).

There are four tasks used to assess each reasoning pattern. For assessing the combinatorial reasoning of students the tasks used are: fun house puzzle, coloured chemicals, hockey player puzzle and electrical switching system (Refer section 4.3.1.1). The data, from Appendix C, show that judge II (Marked 'A' in Appendix C) disagrees only, ten times out of the possible one thousand one hundred and fifty two patterns of disagreements. A total agreement of judge II on the for tasks would be one among the four possibilities viz., II A, II A, II A and II A; II B, II B, II B and II B; III A, III A, III A, and III A; and III B, III B, III B and III B. There are forty eight possible disagreements on the reasoning patterns of each student. Two examples of such disagreements are: 1) II A, II A, II A and II B; and 2) II A, II B, III A and III B. The disagreements of one judge II form only 0.86% of the total possible disagreements, i.e., 16 X 100 / 1152. This is an indicator of the relationship among the four tasks to assess the combinatorial reasoning of students.

A similar analysis on the four tasks to assess 'controlling of variables' show that judge II disagrees eight times out of the possible disagreements. This is only 0.69% of the total possible disagreements.

It may also be noted that the degree of disagreement is only one, i.e., between two adjuscent categories.

4.3.2 Observation schedule (SOCOPSI)

The hypotheses of the study (Chapter III section 3.10. demand a comparison of the experimental and control group 'inputs'. That is, a detailed description of the instructiona process in both the control and experimental groups. In addition to such a comparison, the 'treatment' in the experimental group needs to be described to indicate how the instructional model referred in chapter III (section 3.4.2) operates in an actual classroom situation. It may be mentioned here that the instructional model is based on the same theoretical frame as the 'curriculum reorganising' (Refer chapter III section 3.4.1). It is worthwhile to note what Menon and Bhat (1984) have to say regarding the understanding of an instructional process. They say that 'understanding instruction would mean conceptualising, explaining and predicting its dynamics within a theoretical frame and also critically analysing it'. Reviewing studies involving classroom observation thay mention that the researchers do not seem to appreciate the need of explicati and clarifying their theoretical positions. Neither is there any attempt at articulating the various tenents of an implicit theory and asking meaningful questions, the answers of which would refine the theory. Probably because of the lack of a well articulated rational framework, the observational data

do not seem to be meaningfully collated into further questions and research problems'. The selection of various observation instruments appears to have been made arbitararily and not on the basis of a well articulated theoretical frame justifying its use. Menon and Bhat proposes a relatively unstructured manner, so that, the details of the classroom instructional process are not missed in the process of projecting a preconceived structure on reality. In other words, they suggest that the technique of observation should not limit the possibilities of eliciting such details from the reality. Bhat et. al (1981) have developed an observation schedule which accommodates the qualitative description of a classroom instructional process called "System of Observation of Cognitive Processes in Science Instruction" (SOCOPSI). The SOCOPSI has two major dimensions viz., the behaviour dimension and the process dimension. Details regarding the categories under each dimension, their explanations, and possible patterns of classroom interaction are given in Appendix D. Among the nine patterns described, the instruction through pattern IX would aid the cognitive development of the learners. The above statement is based on two reasons. One, this pattern of classroom interaction tends to approach the Science Instruction Model discussed in chapter III (section 3.4.2). That is, the classroom instructional pattern takes the shape of a cyclic process where; problems are generated,

solutions are hypothesised, invalid ones are rejected, valid ones are accepted, and the accepted ones are integrated into the previous knowledge structures. Two, pattern IX better accommodates the dynamism of the curriculum reorganising discussed in Chapter III (section 3.4.1). That is, the curriculum frame adapting to the cognitive needs of the learners' in a dialectical fashion.

4.3.3 Unstructured interviews

This technique of collecting data is used in the present investigation for three purposes. One, to gather data regarding the influence of peers, siblings, parents and other individuals on the curricular activities of the students interests, hobbies, etc. The objective of gathering such information is to get an insight into the students' interest, or lack of it, in the instructional activities. It may be mentioned here that active participation (in the cognitive sense of the term), is a condition for the development of cognitive structures and reasoning patterns of the learners (Refer chapter III, section 3.8). Two, to collect data regarding the planning and execution of curricular and co-curricular activities of the teacher who taught the control groups. Three, to collect data regarding the admission policy of the school authorities viz., the Principal and the Secratary of the trust which runs the

school. The interviews with the students, the teacher, the principal and the secratary of the school were carried out in informal situations like, the playground, the library, in the corridors, and the staff room of the school[2]. The information thus gathered was recorded by the investigator in the form of anecdotal records. Details of these records are not presented in the body or Appendices of this report because it is too unwieldy. The description of the sample discussed in section 4.2 is partly based on the information gathered using this technique.

The main difference between the unstructured interviews and the clinical interview is that in the former the investigator does not frame any hypothesis on the responses of the interviewee whereas in the latter the investigator (interviewer) frames a certain set of hypotheses on the responses of the interviewee and tests them against the actual responses. It is through the testi of such hypothesis or hypotheses that the investigator assesses the level of reasoning of the interviewee (Refer section 4.3.1.1).

4.4 The Experiment

What follows in this section is the procedure adopte in carrying out the experiment. This is described under fou

subsections viz., pre-assessment of the reasoning patterns of students belonging to one each of the control and experimental groups, curriculum analysis of the chemistry portion of grade IX, description of the treatment of the content and the post-assessment data of all the four groups (two experimental groups and two control groups).

4.4.1 Pre-assessment

Among the four groups detailed in section 4.1 and given in table 4.1, Group 1 and 2 are pre-assessed using th- four tasks from among the pool of eight tasks mentioned in section 4.3.1.1 and described in Appendix B. These observations are mentioned as O_1 and O_3 in section 4.1. Group 1 (experimental group, IX A, N = 50) was pre-assessed during the academic year 1981-'82 and Group 2 (control gro IX A, N = 52) during 1982-'83. Among the four tasks used t assess the reasoning of the students, two were used to ass the 'combinatorial reasoning' and the other two to assess 'controlling of variables'. From among the pool of four tasks to assess the 'combinatorial reasoning' of students two were chosen at random for the pre-assessment using clinical interviews. The tasks chosen are 'fun house puzzle and 'coloured chemicals'. Similarly from among the four ta to assess the 'controlling of variables' of students two tasks are chosen at random for the pretest. The tasks thus

chosen are: 'Photosynthesis puzzle' and 'Pendulum'. The interviewer chose the interviewee from among the group at random. This was done to reduce the probability of students coming to the interview with 'prescribed answers'. Though the above measures would reduce the probability of students coming with prescriptive answers, it does not totally rule out such a possibility. The clinical interview technique has the capability of probing further into these 'prescriptive answers' and making the interviewee come out with 'liberated convictions' or 'spontaneous convictions'. This is a marked advantage of the clinical interview technique over group or individual testing, and pure observation (discussed in detail in section 4.3.1). Sample interviews for each of the eight tasks are given in Appendix E. Appendix E gives only the relevant portions of the sample interviews to highlight the mode of assessment. The sample clinical interviews are chosen in such a way as to give one sample interview from each of the eight tasks giving two examples from the four levels of assessment viz., II A, II B, III A and III B.

The assessment of reasoning of the two groups i.e., Group 1 and Group 2 in the design (Refer section 4.1) are given in the following two tables i.e., table 4.5 and table 4.6.

Table 4.5

The assessment of 'combinatorial reasoning' and 'controlling of variables' of Group 1 students (IX A, 1981-'82). N = 50

Levels of reasoning	Reasoning Patterns			
	Combinatorial reasoning		Controlling of variables	
	Task I	Task II	Task III	Task IV
II A	34	30	40	38
II B	13	18	7	11
III A	3	2	3	1
III B	0	0	0	0

Table 4.6

The assessment of 'controlling of variables' and 'combinatorial reasoning' of Group 2 students (IX A, 1982-'83). N = 52

Levels of reasoning	Reasoning Patterns			
	Combinatorial reasoning		Controlling of variables	
	Task I	Task II	Task III	Task IV
II A	38	34	41	37
II B	13	16	10	14
III A	1	2	1	1
III B	0	0	0	0

The details of the pre-assessment data are given in Appendix F. From the above two tables it is clear that the students reason at the concrete operational level. None of the students operate at the formal operational level (III B).

Only, three students out of fifty in the first group and two out of fifty two in the second group, show any sign of formal operational thinking on any one single task. All these clearly indicate that the majority of the students operate either at early concrete operational level or show signs of transition. Thus objective 1 of the present investigation (refer chapter III, section 3.9) is realised through the above procedure.

4.4.2 Analysis of the chemistry portion of the curriculum frame of grade IX

The second objective of the present study (refer chapter III, section 3.9) is to analyse the chemistry portion of the science curriculum of grade IX based on the level of reasoning manifested by the students. The discussion in the previous subsection (section 4.4.1) and the tables given there clearly indicate that almost all the students of the class operate at the concrete level of reasoning. Therefore, the analysis of the chemistry portion of the prescribed curriculum should aim at concretising the formal concepts so that the students can assimilate them. Also the analysis should aim at creating cognitive conflicts in the students so that the attempts by the students to resolve these conflicts would aid the development of their cognitive structures.

The different units in the prescribed curriculum frame are as follows: 1) Oxygen, 2) Hydrogen, 3) Nitrogen, 4) Phosphorus, 5) Carbon and organic compounds, and 6) The kinetics of chemical reactions. In these units the students are required to learn the physical and chemical properties of the elements mentioned, their preparation, industrial manufacturing process, and uses. Most of these concepts require formal reasoning on the part of the students for proper assimilation. For example, to assimilate a chemical reaction and to predict the 'product' of a reaction when the reactants are given requires propositional logic, combinatorial reasoning and controlling of variables.

Informal interviews with the students to find their background knowledge reveal that they have not developed the concept of matter as particulate. Also, they do not conserve mass which is primarily required to assimilate chemical reactions, predict products and understand the kinetics of chemical reactions.

The content points dealt in the text book are not properly sequenced and interlinked to form a structure. There are several gaps and these are to be filled in suitably to form a total structure. Dealing with the chemical elements as separate units is a clear example of this.

Teaching them as seperate units would not aid the cognitive development, rather it may come in the way. The information thus learnt, by the students, would remain as isolated bits of information with no proper linkage. The students should be able to predict the preparation and properties of elements based on an understanding of the interrelationships of the properties of these elements.

All the above discussed points demand the restructuring of the curricular framework. The restructured curricular framework should fill in the gaps of the existing one, include all basic concepts required to build more complex ones, and should interlink all these into a wholistic structure.

Such a restructuring was done after analysing the content of grade IX. The whole content structure thus reformulated is given in Appendix G thus realising the objective 2 of the study (refer chapter III, section 3.9). It may be mentioned that a mere didactic presentation of the content matter given in Appendix G may not aid the cognitive development of the students (learners). The structure has to adapt itself to the cognitive requirements of the learners. Such an adaptation of the curriculum structure can only be manifested through a dynamic classroom interaction where; data is presented to the learner or recalled from their

repertoire of experiences, to cause cognitive dissonance or conflict in the students. Creating such a conflict, by providing data contradictory to the belief of the students, has two objectives. One, to arouse curiosity or kindle thought processes in students. Two, to initiate a classroom interaction which might lead to resolving the conflict. In a classroom of fifty and above students it is very difficult to involve all the students in the classroom interaction. At the same time it is not conducive from the cognitive development point of view - to restrict the classroom interaction to only a few students in the classroom. Reducing the discussion to a few students would impose restriction on other students from coming out with probable hypothetical solutions to the problem that has risen in the discussion. Therefore, it is necessary to accept all possible hypotheses on the problem from the students and treat them as valid ones until there are contradictions, within the hypothetical solutions or they are disproved by further analysis of data given by any member of the class or the facilitator (teacher). Detailed descriptions of sample instructional interactions are given in Appendix H to show how problems are evolved out of a classroom interaction and how the facilitator guides the interaction in verifying the variety of hypothetical solutions that arise through such discussions. Appendix H describes only two lessons, out of six, observed using

SOCOPS1. It may be mentioned, regarding the tratment lessons that; though attempts at inducing cognitive conflicts are made during each lesson, it might not appeal as conflict to all students of the class. It would appeal to those who actively participate in the classroom interactions. Several such attempts may influence the quantum of participation as well as increase the number of students who participate.

4.4.3 Duration of 'treatment' and 'control'

The Group 1 and Group 3, discussed under the design of the study (see section 4.1), formed the experimental groups. Both these groups, divisions A and B of grade IX, belong to the academic year 1981-'82. The experimental treatment lasted for about six months i.e., the second semester of the academic year 1981-'82. Only the regular science periods provided in the school time-table were used for the treatment. That is, three sessions of fortyfive minutes duration per week. The total number of classes engaged in group 1 (IX A) were forty seven sessions and in group 3 (IX B) were fortyeight sessions. This was of particular interest to the investigator from the point of view of the feasibility of conducting such an experiment with the limitations of an actual classroom with all its constraints. The teacher of the experimental group (here the investigator) was available in the school on all working

days of a week to facilitate individual discussions initiated by the students with the teacher. There were eighteen such small group or individual discussions with the investigator during the period of experimentation[3] (six months). The small group discussions included two to three members at a time.

The investigator was available to the principal of the school to utilise his services when the other regular teachers of the A and B divisions were on leave. During the period of treatment there were eight such sessions with group 1 (IX A) and seven with group 3 (IX B). These sessions were utilised for discussing science related topics or any other topic of general interest of the students. The topics of discussion that came up during these sessions were on space technology, astronomy, meteriology, etc. The choice of topic was left to the students; sometimes it originated from the previous discussions conducted during regular classroom interactions. These sessions may also be seen as part of the experimental treatment, though they were all totally unplanned sessions. Though the sessions were unplanned, they contained an element of guided discovery to the problems that were being discussed. In short, the instructional mode of these sessions were similar to the regular classroom interactions.

Group 2 and group 4 (discussed in section 4.1) forms the two control groups. They are the IX grade A and B divisions of the academic year 1982-'83. The regular teacher of the school taught chemistry for fifty and fifty two sessions respectively in these classes. She had engaged eighteen and fifteen extra sessions respectively which were mainly used to revise the earlier portions or doing 'home work'. The patterns of her classroom interactions are given in Appendix I. Appendix I contains two sample lessions, out of six, of the control group teacher observed using SCOPSI (refer section 4.3.2).

4.4.4 Post-assessment

Towards the end of the II semester of the academic year 1981-'82 the two treatment groups, i.e., IX A and B divisions were assessed. These are group 1 and group 3 of the design of the experiment and the assessments are O_2 and O_5 (refer section, 4.1). The tasks used for the assessment are from the pool of eight tasks described in Appendix E. The tasks which were not used for pre-assessment were used for post-assessment.

They are: 1) Hockey player puzzle (task V), 2) Electrical switching system (task VI), 3) Rate of growth of plants (task VII), and 4) Falling bodies on an inclined

plane (task VIII). As in the case of pre-assessment, the students were called one by one to a room free of disturbances and the tasks were presented to him to act upon. Detailed observations are made on the way the child proceeds to seek an answer. Based on these observations the interviewer assessed their level of reasoning into one of the four categories viz., 1) early concrete (II A), 2) concrete or transitional (II B), 3) early formal (III A) and 4) formal (III B).

Towards the end of II semester of the academic year 1982-'83, the two control groups, i.e., IX A and E divisions, were assessed. These two groups form the group 2 and group 4 of the design of the experiment and the assessments are O_4 and O_5 (refer section 4.1).

The data thus collected from both these sets, i.e., O_2, O_4 and O_5, O_5 are given in Appendix J. The consolidated data are given in the tables 4.7, 4.8, 4.9 and 4.10 ,

Table 4.7

The assessment of reasoning patterns of group 1 students, IX A 1981-'82. (O_2). N = 50.

Levels of reasoning	Reasoning patterns			
	Combinatorial reasoning		Controlling of variables	
	Task V	Task VI	Task VII	Task VIII
II A	19	17	29	30
II B	11	11	13	11
III A	17	17	7	7
III B	3	5	1	2

Table 4.8

The assessment of reasoning patterns of group 2 students, IX A 1982-'83. (O_4). N = 52.

Levels of reasoning	Reasoning patterns			
	Combinatorial reasoning		Controlling of variables	
	Task V	Task VI	TaskVII	Task VIII
II A	30	25	35	34
II B	16	20	13	14
III A	5	6	4	4
III B	1	1	0	0

Table 4.9

The assessment of reasoning patterns of group 3 students, IX B 1981-'82. (05) N = 52.

Levels of reasoning	Reasoning patterns			
	Combinatorial reasoning		Controlling of variables	
	Task V	Task VI	Task VII	Task VIII
II A	22	20	32	31
II B	5	7	9	14
III A	23	21	9	5
III B	2	4	2	2

Table 4.10

The assessment of reasoning patterns of group 4 students, IX B 1982-'83. (06) N = 50

Levels of reasoning	Reasoning patterns			
	Combinatorial reasoning		Controlling of variables	
	Task V	Task VI	Task VII	Task VIII
II A	29	31	37	37
II B	18	16	12	11
III A	3	3	1	2
III B	0	0	0	0

Further analysis and interpretation of the data presented in this chapter are given in the following chapter.

Notes

1. This information is based on an informal interview with the Principal of the school.
2. It may be noted here that such an informal interview was not conducted to all the two hundred and four units of the sample. Rather, it was restricted to three types of students viz., 1) those students who showed disinterest in the classroom interaction, 2) those who were overtly participating in the classroom instruction, and 3) those who have approached the investigator for help.
3. This information regarding the number of informal discussions initiated by the student is from the anecdotal records maintained by the investigator.

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CHAPTER V

ANALYSIS AND INTERPRETATION

5.0 Introduction

The data gathered through the procedures detailed in the previous chapter is analysed and presented in this chapter alongwith the interpretations. The analysis of the data gathered through the SOCOPST is presented, in the first section of this chapter, to highlight the nature of classroom interaction in the experimental and control groups. This is followed by the analyses and interpretation of the data obtained from the experiment described in the preceeding chapter, keeping in view the objectives of the present investigation (refer chapter III, section 3.9). It may be mentioned here that among the five objectives presented in chapter III the realisation of objectives 1 and 2 have already been discussed in chapter IV (refer sections 4.4.1 and 4.4.2). The realisation of objectives 3, 4 and 5 are discussed in this chapter. A process of hypotheses testing is implicit in the realisation of these three objectives. The hypotheses set in chapter III (refer section 3.10) are restated under each sub-section. This is followed by a qualitative analysis of the anecdotal records tracing out the major reasons for the lack of interest in classroom

activities among the students. The chapter concludes with a discussion on the results of the present investigation amidst other studies in the field.

5.1 Classroom Interactions

Six sessions each of the 'treatment' (reorganised curriculum frame) and the control (prescribed curriculum frame) were observed using the System of Observation of Cognitive Processes in Science Instruction (SOCOPSI). The 'instructional events' and the 'instructional episodes' recorded using the SOCOPSI are given in Appendix K. An analysis of the 'instructional episodes' (which contains several 'instructional events') show clearly that they differ in the experimental and control groups. All the six instructional sessions observed, among the treatment, show 'process of inquiry pattern' of instruction (see pattern IX in Appendix D). A closer examination of these episodes reveal that during these interaction sessions the students initiated hypotheses, challenged hypotheses initiated by the teacher, tested hypotheses, accepted or rejected hypotheses, and concluded through the process of testing. In contrast the analyses of the 'instructional episodes' of the control group reveal that they are of 'narration with recall type questions' type (refer pattern III of Appendix D). All the six lessons observed of the control group were of this type. A closer

examination of the instructional episodes reveal that the student initiated questions and hypotheses were given prescriptive answers or explanations by the teacher in the control group. There is no attempt made by the teacher to ignite the thought processes of the students. Here, the treatment of the content is at the information level.

5.2 Effect of Reorganising the Curriculum Frame on the Combinatorial Reasoning of Students

Studying the effect of reorganising the curriculum frame on the combinatorial reasoning of students form a part of the objective of the study (refer objective No. 3, chapter III, section 3.9). The effectiveness can be established in three ways viz., 1) by comparing the difference between the pre and post-assessments of group 1 and group 2 students, i.e., the experimental and control groups (refer chapter IV, section 4.1); 2) by the statistical analyses of the following four pairs of observations i.e., O_2 & O_1, O_2 & O_4, O_5 & O_6, and O_5 & O_3; and 3) by subjecting the post-assessment data to a 2 X 2 analysis of variance as suggested in chapter IV.

5.2.1 Comparison of the gain scores of experimental and control groups

Group 1 and group 2 students have been subjected to pre and post-assessments. They are O_1 and O_2, and O_3 and O_4 respectively as given in the design of the experiment. The

difference in the pre and post-assessments i.e., O_2 minus O_1 and O_4 minus O_3 are computed from the data given in Appendices H and J and presented in table 5.1.

Table 5.1

Improvement in the combinatorial reasoning of students in the experimental and control groups (groups 1 and 2).

Nature of the group	Task V and Task I		Task VI and Task II	
	Not improved	Improved	Not improved	Improved
Experimental N = 50	21	29	23	27
Control N = 52	38	14	38	14

The above table shows that among the students who have undergone the experimental treatment, 58% have improved their reasoning when assessed through a pair of tasks and 54% have improved their reasoning when assessed through a parallel pair of tasks. While, in the control group only 27% of the students show improvement when assessed through both the pairs of tasks. It may be mentioned here that in both the experimental and control groups there is not even a single case where there was a decrease in the level of reasoning. A further analysis of the data, where improvement in the levels of combinatorial reasoning is noted, reveal that the increment has been of only one unit in the case of all the fourteen students of the control group. In the experimental group out of the twentynine students who have shown

improvement, when assessed through the first pair of tasks, the increment is of one unit for twenty two of them and of two units for seven. Similarly, among the twentyseven students who have shown improvement, when assessed through a parallel pair of tasks, the increment is through a degree of one unit among nineteen of them, seven of them show an increment of two degrees and one shows an increment of three units. The increment of increases in the level of reasoning are further elaborated in table 5.2.

Table 5.2
The increment of improvement in the combinatorial reasoning of experimental and control group students

Group	Tasks	Improvement in the level of reasoning					
		II A to II B	II B to III A	III A to III B	II A to III A	II B to III B	III A to III B
Expt.	V & I	9	11	2	6	1	0
	VI & II	7	11	1	5	2	1
Cont.	V & I	8	5	1	0	0	0
	VI & II	9	5	0	0	0	0

It may be noted from table 5.2 that the improvements in the levels of reasoning from concrete (II A) to formal (IIIB) is shown only by the experimental group students whereas among the control group students there is not even a single case of such an improvement. The improvement in the level of reasoning from transitional (II B) to formal (III B)

is shown only by the experimental students. It may also be noted from the table that the number of students who have improved their level of reasoning from transitional (II B) to early formal (III A) is more when compared to the improvement from concrete (II A) to transitional (II B) in the case of the experimental group whereas in the control group the number of students who have improved from II A to II B is more when compared to the improvement from II B to III A. This shows that the treatment is effective in improving the reasoning of students to higher levels when compared to the control group. These evidences clearly indicate the effect of reorganising the prescribed curriculum frame on the combinatorial reasoning of students when compared to the improvement brought out by the existing curriculum frame.

5.2.2 Statistical analyses of the experimental data

In order to conduct a statistical analyses on the experimental data the four levels of reasoning are assigned scores. The scores assigned are as follows: 1 to the level of reasoning II A, 2 to II B, 3 to III A, and 4 to III B. The levels of reasoning from early concrete to formal are in hierarchical order and hence the scores are given in the increasing order from 1 to 4. The scale thus formed is assumed to be of interval scale. Based on the assigned values the means and standard deviations are computed on the six

observations made during the experiment. To test the significance of the difference between the means 't' test is applied on the following four pairs of observations i.e., O_2 and O_1, O_2 and O_4, O_5 and O_6, and O_5 and O_3 to test the following hypothesis:

> There is no difference between the mean scores of the students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the combinatorial reasoning as assessed through tasks.

The above hypothesis is restated from the hypothesis No. 1 given in chapter III, section 3.10. Here the hypothesis is stated in the null form.

Among the four pairs of observations to be subjected to statistical testing O_1 and O_2 are made on the same students and therefore the 't' test applied is for the significance of difference between two means for correlated samples (Ferguson, 1959). The 't' test applied, on the other three pairs of observations, is for the significance of difference between independant samples. The 't' value between the two observations O_2 and O_1 is 7.2 when the assessment is made through task I and task V. The mean score of these two observations O_1 and O_2 are 1.38 and 2.08 respectively. The 't' value is significant at 0.01 level rejecting the null

hypothesis. Observation O_2 has a significantly higher mean than O_1 showing that the experimental treatment has positively influenced the combinatorial reasoning. The 't' value of the difference between means when the assessment is made through task II and task VI is 6.74. This value is also significant at 0.01 level rejecting the null hypothesis in favour of O_2 (mean scores of O_1 = 1.46 and O_2 = 2.2).

The mean, standard deviation and the 't' values for the three pairs of observations O_2 and O_4, O_5 and O_6, and O_5 and O_3 are given in the tables 5.3, 5.4, and 5.5.

Table 5.3

The mean, standard deviation, and 't' values of O2 and O4 for two tasks assessing combinatorial reasoning

Task	Task V		Task VI	
Observations	O_2	O_4	O_2	O_4
N	50	52	50	52
Mean	2.08	1.59	2.2	1.69
S.D.	0.97	0.68	1.02	0.77
't'	2.91**		2.89**	

** significant at 0.01 level

Table 5.4

The mean, standard deviation and 't' values of O_5 and O_6 on two tasks assessing combinatorial reasoning

Tasks	Task V		Task VI	
Observations	O_5	O_6	O_5	O_6
N	52	50	52	50
Mean	2.15	1.52	2.17	1.44
S.D.	1.02	0.64	1.03	0.60
't'	3.69**		4.15**	

** significant at 0.01 level

Table 5.5

The means, standard deviations, and 't' values of O_5 and O_3 on two tasks assessing combinatorial reasoning

Tasks	Task I and V		Task II and VI	
Observations	O_5	O_3	O_5	O_3
N	52	52	52	52
Mean	2.15	1.28	2.17	1.30
S.D.	1.02	0.49	1.03	0.56
't'	5.4**		4.64**	

** significant at 0.01 level

All the above six 't' values are significant at 0.01 level showing that the means of the scores after treatment on the 'combinatorial reasoning' are significantly different from the mean scores of those who were taught through the prescribed

curriculum frame. The strength of such an inference is high since all the experimental group mean scores are higher than those for the control groups.

The analysis of the post test data O_2, O_4, O_5 and O_6 is discussed alongwith the testing of the hypothesis concerning the interaction between pre-assessment and treatment.

5.3 Effect of Pre-assessment on the Combinatorial Reasoning

The need for studying the effect of pre-assessment on the combinatorial reasoning comes from a part of the objective number four of the study (refer chapter III, section 3.9). The hypothesis being tested is as follows:

> There is no difference in the combinatorial reasoning of students, who have been assessed through tasks which demand the use of such reasoning patterns, and those who have not been assessed through such tasks.

The effect of pre-assessment on the combinatorial reasoning can be established by comparing the following two pairs of observations i.e., O_2 and O_5, and O_4 and O_5. The data on the four observations are converted into scores as mentioned in section 5.2.2 and 't' test is applied for testing the significance of the difference between two means for independant samples. The means, standard deviations, and the

't' values for these samples are given in tables 5.6 and 5.7.

Table 5.6

The means, standard deviations, and 't' values of O_2 & O_5 and O_4 & O_6 on task V assessing combinatorial reasoning.

Tasks	Task V		Task V	
Observations	O_2	O_5	O_4	O_6
N	50	52	52	50
Mean	2.08	2.15	1.59	1.52
S.D.	0.97	1.02	0.68	0.64
't'	0.35		0.52	

Table 5.7

The means, standard deviations, and 't' values of O_2 & O_5 and O_4 & O_6 on task VI assessing combinatorial reasoning

Tasks	Task VI		Task VI	
Observations	O_2	O_5	O_4	O_6
N	50	52	52	50
Mean	2.2	2.17	1.69	1.44
S.D.	1.02	1.03	0.77	0.60
't'	0.15		1.83	

All the 't' values shown in the tables 5.6 and 5.7 are not significant indicating that the combinatorial reasoning of students is not influenced by the pre-assessment with a task to assess the same reasonong.

5.4 Analysis of Variance of the Experimental Data

The data gathered through the observations O_2, O_4, O_5 and O_6 are arranged into a 2 X 2 analysis of variance table as shown in chapter IV section 4.1. In such an analysis the two factors taken into consideration are 1) treatment and 2) pre-assessment. The two levels in the treatment are the observations on the two treatment groups and the observations on the 'no treatment' groups. The two levels of assessment are the observations on the pre-assessed and the observations on the not pre-assessed students. Here again the data obtained from the four observations are converted into scores. The scores given are as follows. To the reasoning level II A score one is assigned, to II B score two, to III A score three and to III B score four is assigned. The data given in ppendix J are assigned the values given above before applying the test of analysis of variance. The number of scores in the four cells are not equal. They are as given in table 5.8.

Table 5.8
The number of students in the four groups

	Treatment	No treatment	
Pre-assessed	N = 50 O_2	N = 52 O_4	102
Not pre-assessed	N = 52 O_5	N = 50 O_6	102
	102	102	204

In such a case when the cell frequencies are unequal the first step taken before applying the analysis of variance is to apply a X^2 test on the cell frequencies to find out whether they depart very much from equality. The frequency in the cell corresponding to the r^{th} row and c^{th} column is denoted by n_{rc}. The expected equal frequency is then computed by adding all the n_{rc} and dividing by the number of rows multiplied by the number of columns i.e., N/RC. In the present experiment this value is 204/4 = 51. This value is denoted by $\bar{n}$. The X^2_2 is then computed using the formula $\chi^2 = \sum^{r}\sum^{c} \frac{n_{rc} - \bar{n}}{\bar{n}}$ with RC-1 degrees of freedom. The chi square value thus obtained is 0.0784. For degrees of freedom three the table value is 0.12 at 0.01 level. Therefore it can be inferred that the n in the four cells do not deviate significantly from equality. Following this a simple adjustment to the sum and sum of squares for each cell is made by multiplying the respective values by $\bar{n}/n_{rc}$. This adjustment estimates what the cell sum and sum of squares would be, were there an equal number of cases $\bar{n}$ in each cell. The adjusted cell sums and sums of squares are used to obtain the row and column totals and the total sum of squares. Further analysis of variance is carried out employing computational formulas given by Ferguson (1959, p.254).

The above discussed procedure was adopted for the

analysis of variance on the four observations O_2, O_4, O_5 and O_6 made on the students using task V and task VI for assessing the combinatorial reasoning. The summary of these two analyses are given in tables 5.9 and 5.10. The hypotheses being tested through this 'F' test are as follows:

1. There is no difference between the mean scores of the students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the combinatorial reasoning as assessed through tasks.

2. There is no difference in the combinatorial reasoning of students, who have been assessed through tasks which demand the use of such a reasoning pattern, and those who have not been assessed through such tasks.

3. There is no difference in the 'combinatorial reasoning' of students, who have been pre-assessed on the same reasoning pattern and who have undergone the treatment (the reorganising of the science curriculum), and who have not been pre-assessed and not undergone the treatment; and those who have not been pre-assessed and who have undergone the treatment and those who have been pre-assessed but not undergone the treatment.

Among the three hypotheses stated above, the first one is restated from hypothesis No. 1 given in chapter III section 3.10. The second and third are from hypotheses No. 3 and 5 given in the same section.

Table 5.9

Summary of analysis of variance on the combinatorial reasoning scores assessed through task V

Source of variance	Sum of squares	Degrees of freedom	Variance estimate	F value
Rows (pre-ass.)	0.00013	1	0.00013	0.00017
Columns (treatm.)	15.91	1	15.91	20.94**
Interaction	0.2699	1	0.2699	0.3552
Within	151.93	200	0.7596	
Total	168.11	203		

for df of 1 and 200 the values at 0.05 = 3.89 and 0.01 = 6.76

** significant at 0.01 level

Table 5.10

Summary of analysis of variance on the combinatorial reasoning scores assessed through task VI

Source of variance	Sum of squares	df	Variance estimate	F value
Rows (pre-asses.)	0.99	1	0.99	1.26
Columns (treatment)	19.61	1	19.61	24.86**
Interaction	0.63	1	0.63	0.79
Within	157.8	200	0.78	
Total	179.03	203		

** significant at 0.01 level

The F values in tables 5.9 and 5.10 show that the null hypothesis number one is rejected and the other two,

null hypotheses are not rejected. This indicates that the treatment has an influence on the combinatorial reasoning of students whereas the pre-assessment as well as the interaction, caused because of the treatment and pre-assessment, do not have any significant effect on the combinatorial reasoning.

The significant F value of 24.86 for the treatment effects calls for further analysis of the observations O_2 & O_4 and O_5 & O_6 by subjecting these observations to 't' tests. This has already been detailed in section 5.2.2.

5.5 Effect of Maturation and History on the Combinatorial Reasoning

A comparison of observation O_6 with O_1 and O_3 seperately would indicate the combined effect of maturation and the effect due to the instruction through the prescribed curriculum frame on the combinatorial reasoning of students. Tables 4.5, 4.6 and 4.10 given in chapter IV present the data collected through observations O_1, O_3 and O_6 respectively. These data are further subjected to statistical analysis. The mean, standard deviation and 't' values of O_6 with O_1 and O_6 with O_3 are given in table 5.11.

Among the four 't' values only the one between O_6 and O_3 when assessed through task I and V shows a significance

Table 5.11

The Means, standard deviations, and 't' values of O_6 with O_1 and O_6 with O_3 through two pairs of tasks assessing 'combinatorial reasoning'.

	Task I and Task V			Task II and Task VI		
	O_1	O_6	O_3	O_1	O_6	O_3
N	50	50	52	50	50	52
Mean	1.38	1.52	1.26	1.46	1.44	1.38
S.D.	0.59	0.64	0.49	0.60	0.60	0.56
't'	1.12		2.1*	0.18		0.55

* significant at 0.05 level

in the difference of the mean scores. All the other 't' values are not significant. This shows that the effect of maturation and history on the combinatorial reasoning is marginal. One 't' value being significant is insufficient evidence to conclude that there is a positive effect due to maturation and history within a period of six months.

5.6 Effect of Reorganising the Curriculum frame on the Controlling of Variables of Students

Studying the effect of reorganising the prescribed curriculum frame on the 'controlling of variables' of the students form part of the objective No. 3 of the present investigation (refer chapter III, section 3.9). The effectiveness can be established in three ways viz., 1) by comparing the difference between the pre and post-assessments

of group 1 and group 2 students i.e., the experimental and control groups (refer chapter IV, section 4.1), 2) by the statistical analyses of the following four pairs of observations i.e., O_2 & O_1, O_2 & O_4, O_5 & O_6, and O_5 & O_3, and 3) by subjecting the data obtained through O_2, O_4, O_5 and O_6 to a 2 x 2 analysis of variance as suggested in chapter IV, section 4.1.

5.6.1 Comparison of the gain scores of experimental and control groups

Group 1 and group 2 students have been subjected to pre and post-assessments. These are observations O_1 and O_2 on group 1 and O_3 and O_4 on group 2. The difference in the levels of reasoning as observed through the pre and post-assessments i.e., O_2 minus O_1 and O_4 minus O_3 are computed from the data given in Appendices F and J. These differences are presented in table 5.12

Table 5.12
Improvement in the 'controlling of variables' of students in the experimental and control groups

Nature of the group	Task III and VII		Task IV and VIII	
	Not improved	Improved	Not improved	Improved
Experimental N = 50	35	15	37	13
Control N = 52	42	10	46	6

Table 5.12 shows that among the students who have undergone the experimental treatment 30% have improved their reasoning when assessed through a pair of tasks (task III & task VII) and 26% have improved their reasoning when assessed through a parallel pair of tasks (task IV and task VIII). While, in the control group only 19.2% improved their reasoning when assessed through the tasks III and VII and 11.5% of the students improved their reasoning when assessed through the tasks IV and VIII. A further analysis of the data, where improvement in the reasoning is noted, reveal that the improvement has been of only one unit in all the sixteen cases (10+6) of the control group. In the experimental group out of the fifteen students who have shown improvement, when assessed through the first pair of tasks, the improvement in the levels of reasoning is of one unit among eleven of them and of two units in the rest four. Similarly, among the thirteen students who have shown improvement, when assessed through a second pair of tasks, the improvement is through a degree of one unit for nine of them, three show an increment of two units and one shows an increment of three units. The improvements in the level of reasoning are further detailed in table 5.13.

It may be noted from table 5.13 that in the control group the improvement in the level of reasoning is confined

Table 5.13

The improvements in the controlling of variables of experimental and control groups assessed through two pairs of tasks

Group	Tasks	Improvements in the level of reasoning					
		II A to II B	II B to III A	III A to III B	II A to III A	II B to III B	II A to III B
Expt.	III & VII	8	2	1	4	0	0
	IV & VIII	6	2	1	2	1	1
Cont.	III & VII	7	3	0	0	0	0
	IV & VIII	3	3	0	0	0	0

to the reasoning levels II A to II B and II B to III A. Among the experimental students there are higher level of improvement i.e., from III A to III B, II A to III A, and also II A to III B. Though the number of students who have improved by two and three increments are few, these increments are due to the treatment. All these indicate the positive influence of the reorganising of the prescribed curriculum on the reasoning (controlling of variables) of students when compared to the control group.

5.6.2 Statistical analysis of the data

Based on the experimental design there are six observations made i.e., O_1, O_2, O_3, O_4, O_5 and O_6

(see chapter IV, section 4.1). The data obtained through these observations are in the form of categories viz., II A (early concrete), II B (transitional), III A (early formal) and III B (formal). These four levels of reasoning are assigned scores 1, 2, 3 and 4 respectively as discussed earlier (refer section 5.2.2). With these assigned values the means and standard deviations are computed for the observations made. In order to establish the effectiveness of the treatment the following four pairs of observations are subjected to 't' test. The observations are: O_1 and O_2, O_2 and O_4, O_5 and O_6, and O_5 and O_3. The hypothesis being tested through these four 't' tests on the observations is as follows:

> There is no significant difference between the mean scores of the groups of students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the controlling of variables of students as assessed through tasks.

The above hypothesis is restated based on hypothesis No. 2 stated in chapter III, section 3.10. Here it is stated in the null form.

Among the four pairs of observations to be subjected to testing O_1 and O_2 are made on the same students and

therefore, the 't' test meant for testing the significance of difference between two means for correlated samples is applied (Ferguson, 1959 p.139). The 't' test applied on the other three pairs of observations, is the test of significance of difference between two means for independent samples (Ferguson, p.137). The 't' values between the two observations O_2 and O_1 is 4.0 when the assessment is made through task III and task VII. The mean scores of these two observations O_1 and O_2 are 1.26 and 1.62 respectively. The 't' value is significant at 0.01 level leading to the rejection of the null hypothesis. Observation O_2 has a significant mean difference with O_1 showing that the experimental treatment has positively influenced the reasoning (controlling of variables) of students. The 't' value of the difference between means when the assessment is made through task IV and task VIII is 3.67. This value is also significant at 0.01 level, rejecting the null hypothesis in favour of O_2. The observations through the second pair of tasks also show that the treatment is effective.

The means, standard deviations, and 't' values for the three pairs of observations O_2 & O_4, O_5 & O_6, and O_5 & O_3 are given in tables 5.14, 5.15 and 5.16.

Table 5.14

The Means, Standard Deviations, and 't' values of O_2 and O_4 on two tasks assessing the 'controlling of variables'

Tasks	Task VII		Task VIII	
Observations	O_2	O_4	O_2	O_4
N	50	52	50	52
Mean	1.62	1.4	1.62	1.42
S.D.	0.79	0.63	0.87	0.63
't'	1.57		1.32	

Table 5.15

The Means, Standard Deviations, and 't' values of O_5 and O_6 on two tasks assessing 'controlling of variables'

Tasks	Task VII		Task VIII	
Observations	O_5	O_6	O_5	O_6
N	52	50	52	50
Mean	1.63	1.28	1.57	1.3
S.D.	0.92	0.49	0.82	0.53
't'	2.36*		1.94	

Table 5.14 shows that, though O_2 has higher mean compared to O_4 when assessed through tasks VII and VIII, the mean differences are not significant. Table 5.15 shows that the means of the experimental group observations O_5 are higher when assessed through the tasks VII and VIII. The mean difference is significant at 0.05 level when assessed

Table 5.16

The Means, Standard Deviations and 't' values of O_5 and O_3 on two tasks assessing 'controlling of variables'

Tasks	Task III and VII		Tasks IV and VIII	
Observations	O_5	O_3	O_5	O_3
N	52	52	52	52
Mean	1.63	1.23	1.57	1.28
S.D.	0.92	0.46	0.82	0.49
't'	2.77**		2.16*	

* significant at 0.05 level

** significant at 0.01 level

through task VII whereas when assessed through task VIII the 't' value falls short of the significantly different value. (the 't' value to be significant at 0.05 level is 1.98). Table 5.16 shows that the experimental group observation O_5 have significantly higher means when assessed through both the pairs of tasks (tasks III & VII and tasks IV & VIII). The strength of the inference is reduced since three out of the eight 't' values are not significant. From the five 't' values which are significant it may be inferred that the treatment is effective in improving the reasoning (controlling of variables) of the students. This inference may be further strengthened by subjecting the observations O_2, O_4, O_5 and O_6 to analysis of variance (see section 5.8).

5.7 Effect of Pre-assessment on the 'Controlling of Variables'

The need for studying the effect of pre-assessment on the 'controlling of variables' form a part of the objective number four (refer chapter III section 3.9). The hypothesis being tested is as follows:

> There is no difference in the 'controlling of variables' of students, who have been assessed through tasks which demand the use of such reasoning pattern, and those who have not been assessed through such tasks.

The effect of pre-assessment on the 'controlling of variables' can be established by comparing the following two pairs of observations i.e., O_2 & O_5 and O_4 & O_6. The data gathered through these four observations are converted into scores as mentioned in section 5.2.2 and 't' test is applied for the significance of difference betwen two means for independent samples. The means, standard deviations and the 't' values are given in tables 5.17 and 5.18.

Table 5.17

The Means, Standard Deviations and 't' values of O_2 & O_5 and O_4 & O_6 as assessed through task VII

	O_2	O_5	O_4	O_6
N	50	52	50	52
Mean	1.62	1.63	1.4	1.28
S.D.	0.79	0.92	0.63	0.49
't'	0.05		1.22	

Table 5.18

The Means, Standard Deviations, and 't' values of O_2 & O_5 and O_4 & O_6 when assessed through task VIII

	O_2	O_5	O_4	O_6
N	50	52	50	52
Mean	1.62	1.57	1.42	1.3
S.D.	0.87	0.82	0.63	0.53
't'	0.27		1.02	

The 't' values in both the tables 5.17 and 5.18 are not significant and therefore the null hypothesis is not rejected. It may be inferred that the pre-assessment does not influence the 'controlling of variables' of students.

5.8 Analysis of Variance on the Experimental Data

The data gathered through the experiment, O_2, O_4, O_5, and O_6 are arranged into a 2 X 2 analysis of variance table as shown in chapter IV section 4.1. The four sets of observational data are converted into scores as detailed in section 5.2.2. The number of units in each cell is not equal and therefore, before applying the analysis of variance, adjustments are made on the cell sums and sum of squares as detailed in section 5.4. The summary of the analysis of variance on the controlling of variables observational data are given in tables 5.19 and 5.20. The hypotheses being tested through this 'F' test are as follows:

1. There is no difference between the mean scores of the students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the 'controlling of variables' as assessed through tasks.
2. There is no difference in the 'controlling of variables' of students, who have been assessed through tasks which demand the use of such a reasoning pattern, and those who have not been assessed through such tasks.
3. There is no difference in the 'controlling of variables' of students, who have been pre-assessed on the same reasoning pattern and who have undergone the treatment (the reorganising of the science curriculum), and who have not been pre-assessed and not undergone the treatment; and those who have been pre-assessed and who have undergone the treatment, and those who have been pre-assessed but not undergone the treatment.

Among the three hypotheses stated, the first one is restated from hypothesis No. 2 given in chapter III, section 3.10. The second and third are the hypotheses numbered 4 and 6 in the same section.

The F values in tables 5.18 and 5.19 show that the null hypothesis, number one, stated in this section, is rejected and two and three are not rejected. This indicates that the treatment has an influence on the reasoning (controlling of variables) of students whereas

Table 5.19

Summary of Analysis of Variance on the 'Controlling of Variables' scores when assessed through task VII

Source of variance	Sum of squares	df	Variance estimate	F
Rows (pre-ass.)	0.15	1	0.15	0.27
Columns (treat.)	4.15	1	4.15	7.68**
Interaction	0.24	1	0.24	0.44
Within	108.20	200	0.54	
Total	1[illegible]2.74	203		

For df 1 & 200 the value at 0.05 = 3.89 and 0.01 = 6.76

** significant at 0.01 level

Table 5.20

Summary of Analysis of Variance on the 'Controlling of Variables' scores when assessed through task VIII

Source of variance	Sum of squares	df	Variance estimate	F
Rows (pre-ass.)	0.44	1	0.44	0.83
Columns (treat.)	3.11	1	3.11	5.86*
Interaction	0.04	1	0.04	0.07
Within	107.52	200	0.53	
Total	111.11	203		

* significant at 0.01 level

the pre-assessment and interaction caused because of treatment and pre-assessment do not have any significant effect on the 'controlling of variables of students.

The significant F values of 7.68 and 5.86 shown in tables 5.19 and 5.20 call for further analysis of the observations O_2 & O_4 and O_5 & O_6 by subjecting these observational scores to 't' tests. This has already been detailed in section 5.6.2.

5.9 Effect of Maturation and History on the Controlling of Variables

A comparison of observations O_6 with O_1 and O_3 would indicate the combined effect of maturation and the effect due to the instruction through the prescribed curriculum frame on the reasoning (controlling of variables) of the students. Tables 4.5, 4.6 and 4.10 given in chapter IV present the data collected through observations O_1, O_3 and O_6 respectively. This data is further subjected to statistical analysis. The means, standard deviations, and 't' values of O_6 with O_1 and O_6 with O_3 are given in table 5.21.

All the four 't' values presented in table 5.21 are not significant. This clearly indicates that the effect of maturation and history on the controlling of variables is marginal. The mean is higher in case of O_6 when compared to O_1 and O_3 when assessed through both the pairs of tasks. This indicates that due to maturation and histrory there is improvement in the reasoning but, within six months the difference is not significant.

Table 5.21

Means, Standard Deviations, and 't' values of O_6 with O_1 and O_6 with O_3 through two pairs of tasks assessing controlling of variables

Tasks	Tasks III and VII			Tasks IV and VIII		
Observations	O_1	O_6	O_3	O_1	O_6	O_3
N	50	50	52	50	50	52
Means	1.25	1.28	1.23	1.26	1.3	1.28
S.D.	0.56	0.49	0.46	0.48	0.53	0.49
't'	0.23	0.53		0.41	0.21	

5.10 Analyses of the Anecdotal Records

Though the acceleration or improvement in the reasoning patterns viz., 1) combinatorial reasoning and 2) controlling of variables are statistically significant all the students in the experimental group have not shown improvements. It may be observed here that the assumption of the experiment is that students will actively participate in the classroom interaction so that their reasoning patterns would develop (refer chapter III, section 3.8). The analyses of the anecdotal records maintained by the investigator indicates a general lack of interest in the instructional activities by many students. The lack of interest originate from different basic reasons for different students. A few of them who have been informally interviewed indicate that one of the main reasons is because of the security they forsee

in their future prospects. They know that the formal education is not going to help them much with their future plans. Their parents and guardians are involved in business and they are sure that they would enter the same as soon as they are mature to take over. The above point may be further elaborated with an example from the anecdotal records. DRS (age 15 years, 6 months) belong to group 1 of the design. That is, the pre-tested experimental group. He was one among the many who did not participate in the classroom discussion even when information seeking questions are directed to him. During the interview he indicated that his father owns three sweet meat shops in the city. Two of these shops are managed by his elder brothers and the third shop presently run by his father would be handed over to him as soon as he is mature. On the investigators suggestion that formal education can help him better with his business, he replied that, what is possible has already been acquired, i.e., basic mathematics, and to read and write in English and Gujarati. The above illustration is only one among similar instances where students have expressed their reasons for the lack of interest in the classroom interactions. It may also be mentioned here that the pre and post-assessments of the boy indicates that he has not shown any improvement in the 'combinatorial reasoning' and 'controlling of variables'.

Another major reason for the lack of interest among the students in instructional activities is the over anxiety to score high in the examination. The students show a general tendency to show interest in only those activities which would directly help them in getting more marks in the examinations and a lack of interest in actively participating in the classroom interactions through which they would discover the laws and principles of nature. Such a tendency of 'examination orientation' is shown even by those who actively participate in the classroom discussions. An illustration from the anecdotal records may further explain this point. Two students of the pretested experimental group on approaching the investigator with a content clarification in Physics, were suggested to do the experiments in the laboratory so that they may discover the law. The investigator offered to help. The immediate response of the students was that they have a 'test' the next day and just needed only an explanation of the experiment and expressed their disinterest in doing the actual experiment. The above illustration clearly indicates how the natural curiosity of the students is curbed by the overemphasis on 'test' or examination oriented teaching.

From the analyses of the anecdotal records a third major reason that has emerged is the medium of instruction.

of normal classroom students the reorganising of the prescribed curriculum can initiate cognitive dissonance in students and thus improve their reasoning patterns.

5.11 Discussion

The analyses of the experimental data clearly indicates that the experimental treatment is effective in accelerating the 'combinatorial reasoning' and 'controlling of variables' of students. But, the improvement in the 'controlling of variables' is to a lesser extent when compared to the 'combinatorial reasoning'. This is based on two observations. One, the number of students who have improved their reasoning (controlling of variables) is less when compared to the number of improvements in 'combinatorial reasoning'. Two, the improvements in the reasoning indicated through the pre and post-assessments indicate that those who have shown improvements in the 'controlling of variables' have also improved their 'combinatorial reasoning'; but, the reverse is not true. That is, all those who have shown improvements in the 'combinatorial reasoning' have not improved their reasoning in 'controlling of variables'. It may be mentioned here that both the reasoning patterns 'combinatorial reasoning' and 'controlling of variables' form parts of the formal reasoning structure. Such a difference in the reasoning patterns exhibited by the students, i.e.,

manifesting formal reasoning when assessed through one task, and not when assessed through a related task, is termed as horizontal décalage in the Piagetian theoretical framework (refer chapter III, section 3.6). This finding, of a horizontal décalage in the closely related reasoning patterns, is contradictory to the findings of the earlier studies (Karplus, 1979; Wollman & Chen, 1982; and Lawson et. al. 1975). But, there is a psychological link between the 'combinatorial reasoning' and 'controlling of variables'. That is, the generation of all possible combination of variables in a given situation is required for an individual to 'isolate' and 'control' variables. Such a psychological link has been already suggested by Lawson (1979), and the findings of the present study also indicate the same.

The acceleration of the reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables' is in agreement with studies conducted under different field conditions. The strategy used for acceleration in the present investigation has common characteristics with those studies (studies conducted under field conditions different from that of the present investigation). For example, Broddermann (1973) used a cognitive conflict strategy to accelerate the ability to control variables among young adolescents. This strategy has the common characteristic of inducing cognitive conflict

in the learners with the instructional model used in this study. The main difference is that Bredderman used an individual focused mode of instruction whereas the present study has used a group instructional model. A similar group instructional model, called 'learning cycles', is used by McKinnon & Renner (1971) and Smith & Von Egerene (1977) to accelerate 'combinatorial reasoning' and 'controlling of variables'. The strategy used by these researchers focused more on the manipulation of objects when compared to the model used in the present study. The field conditions in the present investigation did not permit such a possibility, of manipulation of objects by each student, because of the non-availability of adequate facilities in the school where the experiment was conducted.

Among the various strategies used by researchers for accelerating the formal reasoning patterns there are two strategies which resemble the instructional model used in the present study. They are: 1) the peer interaction model used by Ward (1979) and 2) the social interaction model used by Wollman and Chen (1982). The main characteristic which is common to these two instructional strategies and the one used in this study is the element of group interaction. The findings of the present investigation are in agreement with those where group interaction strategies have been used.

The feature which differentiates the instructional model used in the present study from those referred above, is the epistemic characteristic of instruction. That is, the curriculum reorganisation has been carried out based on the historical development of the concepts, principles and laws. This characteristic makes the model of instruction used in the present study, more suitable for concrete operational learners, than the ones used by other researchers referred in chapter II.

The mode of instruction in the control groups of the present investigation was not based on any specific theoretical grounds. The lack of acceleration in these groups may be attributed to such a lacuna in the instructional mode. This mode of instruction may be taken as one that goes on in a 'normal' classroom. Sandeep (1979) after surveying the relationship between the classroom interaction pattern and cognitive development on Indian sample reports that the classroom interaction adversely affects the cognitive skills. The 'steady state' of the reasoning patterns in the control groups may be because of such an adverse effect.

The guided inquiry approach to instruction used in the experimental group of the present study is found successful in accelerating the reasoning patterns whereas the didactic presentation of content matter was not successful. The acceleration of the reasoning patterns may be seen similar to

the improvement in problem solving abilities. That is, the students who have improved their reasoning patterns will be able to perceive the different variables in a problem situation and isolate and control variables effectively in finding a solution. This finding of the present study is in agreement with the one conducted by Ajwani (1979) where he tried to accelerate the problem solving ability by guided discovery, through learning puzzles and by giving specific directions. He found that guided discovery is better than the other two approaches in accelerating the reasoning. Also, the study conducted by Yadav (1982) shows the superiority of guided discovery over lecture method in accelerating concepts. It may be mentioned here that, in the studies conducted by Ajwani and Yadav the experimental inputs are not directly related to the prescribed curriculum of the grades, whereas the present investigation focused on the reframing of the prescribed curriculum frame for the grade.

Though the present investigation has shown that acceleration of logical reasoning is possible through the reorganised curriculum frame, it cannot be taken as conclusive evidence. Further research in this area under varied field conditions is required to conclude on the possibility of accelerating logical reasoning patterns under field conditions. Also, the model of instruction used in this study has to be

compared with other models of instruction before concluding on its merits. Based on these lines a few studies are suggested for further research in the concluding chapter of this report alongwith the summary.

REFERENCES

All references that appear in this chapter have already appeared in chapter II of this report (see references given at the end of chapter II), except for the one given below.

FERGUSON, G.A. Statistical Analysis in Psychology and Education. New York: McGraw Hill, 1959.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.0 Introduction

In this concluding chapter of this report a brief summary of the study is presented. A short description of the theoretical basis is given followed by the presentation of the problem and the objectives of the study. A brief description of the procedure adopted for the realisation of the objectives is presented next. This is followed by a short description of the analysis and the major findings of the study. The chapter concludes with a discussion on the implications that can be derived from the present study for future research in the field of Science Education.

6.1 Theoretical Background

At a given point of time in the history of the evolution of human knowledge the understanding of various phenomena and their interrelationships exists in the form of a well connected structure. The structure is internally consistent and that it accounts for almost all observations made during that time. When contradictory observations are made, they are either rejected as invalid or modified to fit into the structure. When an observation or a set of

observations, does not fit into the structure there arises a need from within the structure to undergo modifications; thus evolving into a new stage. Human knowledge has evolved through several such stages. An individual right from his childhood, interacts with his environment and adapts cognitively. He progressively constructs his cognitive structure through active interaction with his surroundings. His construction of cognitive structures also undergo similar stages of evolution like the human knowledge structure. Such an idea of an isomorphism between the knowledge generated by mankind over generations and how an individual constructs his cognitive structures is implicit in the theory of cognitive development propounded by Jean Piaget, a Swiss psychologist. Piaget's theory of cognitive development suggests four major stages in the mental development of a child. They are: sensorimotor, pre-operational, concrete operational and formal operational. These stages are characterised by the mental operations a child is capable of manifesting at a point of time. Major changes in the logical reasoning patterns occur when a child transits from one stage to another. The need for the transition comes from within the cognitive structure of the child. The structures grow as a child moves up from one stage to another. Older structures are not replaced by newer ones but are integrated with. The order of the stages is consistent and sequential.

The cognitive development of a child is influenced by two factors viz., 1) certain organisers inherent in the system determined by genetic factors and 2) environment. The environment comprises mainly of casual experiences and organised social experiences. One of the main forms of organised social experiences is formal education. Since the development of logical reasoning is dependent on social environment and experiences in general, designing instruction suitably should influence the cognitive development. In the natural development the need for restructuring ones cognitive structure comes from the failure to explain certain observations with the existing reasoning patterns. These reasoning patterns form a part of one's cognitive structure by means of which an individual explains an observation or a set of observations. When one fails to explain an observation, he feels the need to modify the reasoning patterns and thus affecting a change in his cognitive structure. So, it may be possible to induce the need for changing one's cognitive structure through constantly posing challenges to his knowledge structure or data that would contradict with his reasoning and help him resolve the contradiction. Normally the tendency of an individual would be to explain the observations with his existing reasoning patterns of his cognitive structure. But, the instructor may have to constantly point out the internal contradictions when such explanations are

made and if the individual realises it as a contradiction, the need for changing the cognitive structure would come from within.

6.2 Attempts at Accelerating Logical Reasoning

Earlier attempts on accelerating the logical reasoning patterns in laboratory and quasi-laboratory conditions indicate that transitional students are more prone to acceleration rather than those who are in an early stage of development. Rigid structuring of experiences does not show much of an influence on improving the logical reasoning. Attempts at influencing the reasoning patterns of students after taking into consideration their previous knowledge and existing cognitive structures, and framing experiences based on these have shown positive results. An inquiry approach to teaching is found to accelerate reasoning when compared to expository or didactic mode of teaching. Previous attempts at accelerating the logical reasoning patterns also indicate that creating 'cognitive conflict' as a strategy has been successful in developing cognitive structures and also the reasoning patterns. Acceleration studies conducted on Indian students are mainly confined to laboratory type of conditions where no attempt is made to reorganise the curriculum frame or relate the treatment to instructional activities

prescribed for the grade. Here, arises the need for conducting field studies attempting at accelerating the logical reasoning in the actual classrooms given all its constraints. Also, there is a need to relate the classroom experiences tothe curriculum frame prescribed for the grade. Taking this research need into consideration, the present study makes an attempt at influencing the reasoning of students through actual classroom teaching based on the prescribed curriculum frame.

6.3 The Bases of the Present Problem

Among the school subjects 'science' is the most appropriate one to attempt at accelerating the reasoning. This is because of the reason that 'science' gives a lot of scope for the students to act upon with the physical environment and through these actions they construct mental structures and concomittantly develop their reasoning patterns. A review of the field conditions in India indicates that the science curriculum frame is outdated and disorganised. The curriculum framing is not based on any theoretical frame. The curriculum demands a lot of hardwork from the students in rote memorising the facts, principles, etc. There is hardly any provision for the students to act upon objects and ideas and discover the laws and principles

of natural phenomena. The curriculum experiences are rather presceptive and curb the students from thinking in an original manner. The present study attempts at answering the question whether it is possible to influence the reasoning patterns of the learners' under the field conditions.

A total reorganisation of the curriculum frame may have to be done in the light of 1) the previous concept structure of the learners and 2) the logical reasoning patterns they are capable of manifesting, for an attempt at accelerating the reasoning patterns. The need for reorganisation becomes all the more meaningful in the Indian context because the students of a particular grade have undergone through the static and ill-prepared curriculum during the previous years of learning. Also, the reorganisation should be done in consideration to the conceptual structure of the discipline. Such a reorganisation of the curriculum frame should make it highly flexible and dynamic. The dynamism and flexibility of the curriculum frame may be seen in terms of its adaptability to the various cognitive demands of the learners, so that their reasoning patterns are accelerated. This calls for the use of an instructional model of science which is also dynamic in nature. The model of instruction should include the ingredient of an inquiry approach. A guided inquiry approach

where the teacher acts as a facilitator to the process is more appropriate than a pure inquiry approach. Earlier attempts clearly support this view. The facilitator may continually assess the knowledge structure of the learners and provide data in such a way as to cause cognitive conflicts in their mind. This would stimulate the students to come out with several hypotheses. The facilitator may then help the students in testing these hypotheses by recalling day to day experiences or by supplying appropriate data (pre-fabricated or from the history of science). These tested hypotheses get integrated to the cognitive structures of the learner. By such a cyclic process the learners construct their cognitive structures and improve their reasoning (mental operations).

In the intellectual development model propounded by Piaget the mental operations appear during the concrete operational stage. An early concrete operational child may need a long term interaction with the environment to transform to the formal operational stage. The instruction of formal concepts may not be beneficial to such a student as he is not equipped to assimilate such concepts. Therefore, it may be worthwhile to attempt at influencing the reasoning patterns of students when they are in a transitional state from concrete to formal. Preliminary investigations

conducted by the investigator indicate that among the secondary classes, grade IX and X students show transition from concrete to formal operational thought. Among these two grades, grade IX is chosen for the present study.

A few examples of reasoning patterns that can differentiate between the concrete and formal operational student are 1) combinatorial reasoning 2) controlling of variables 3) proportional reasoning and 4) deduction. These reasoning patterns are inter related - some closely and others remotely. Some of these reasoning patterns evolve to a higher level faster when compared to others. This is termed as 'horizontal décalage' in the Piagetian theoretical framework. From the point of view of assessing the reasoning patterns and attempting at accelerating these patterns, it would be better to choose closely related reasoning patterns. Also, the choice of reasoning patterns should be based on the possibilities the science curriculum offer for its acceleration. Based on these criteria the reasoning patterns 'combinatorial reasoning' and 'controlling of variables' are chosen in the present study. Therefore, the research question of the present study boils down to whether the reorganising of the prescribed curriculum frame of grade IX to suit the level of reasoning of students would aid the development of the same reasoning pattern in an actual

classroom situation given all its natural constraints. There is a basic assumption behind this question. That is, an active participation by the students on the curriculum material presented to them would aid cognitive development.

6.4 The Problem of the Study

A STUDY OF THE EFFECT OF REORGANISING THE PRESCRIBED CURRICULUM FRAMEWORK ON THE COMBINATORIAL REASONING AND CONTROLLING OF VARIABLES OF GRADE IX STUDENTS.

The study is aimed at accelerating the logical reasoning of students with the aid of curricular experiences in a real classroom setting, with all its natural interferences. The two logical reasoning patterns that are accelerated are 1) combinatorial reasoning and 2) controlling of variables. The chemistry portion of the science curriculum prescribed for the grade is selected for reorganising. The reorganising is carried out based on the three criteria viz., 1) the background knowledge of the students, 2) the reasoning patterns manifested by the students and 3) the structure of the discipline.

6.4.1 Objectives of the study

The major objectives of the study can be stated as follows:

1. To assess the level of reasoning of students of grade IX in the following reasoning patterns
   (a) combinatorial reasoning and (b) controlling of variables.

2. To analyse the chemistry portion of the science curriculum of grade IX with a view to reorganising it to suit the level of reasoning of students.

3. To study the effect of reorganising the curriculum frame on the following reasoning patterns
   (a) combinatorial reasoning and (b) controlling of variables in comparison to the existing curriculum frame.

The assessment of the level of reasoning (objective No. 1) demands the use of problems or tasks to be presented to the students and observiving the way they go about solving it. The exposure to such problems or tasks might interfere with studying the effect of the treatment (objective No. 3). Here arises the need to study the effect of the pre-assessment and its influence on the treatment. Therefore, the following two objectives are added alongwith the above three.

4. To study the effect of assessment of the reasoning patterns (a) combinatorial reasoning and
   (b) controlling of variables on the development of the same.

5. To study the interaction between the pre-assessment and treatment on the two reasoning patterns
   (a) combinatorial reasoning and (b) controlling of variables.

6.4.2 Hypotheses of the study

The following hypotheses are tested in the present investigation.

1. The reorganisation of the chemistry portion of the science curriculum for grade IX may positively influence the combinatorial reasoning of students who undergo the classroom instruction with reorganising the prescribed curriculum when compared to those students who undergo the normal classroom teaching based on the existing curriculum frame.
2. The reorganising of the chemistry portion of the science curriculum for grade IX may positively influence the 'controlling of variables' of students who undergo the classroom instruction with the reorganising of the prescribed curriculum when compared to those students who undergo the normal classroom teaching based on the existing curriculum frame.

The above hypotheses have been framed in the directional form since earlier attempts show that acceleration is possible under laboratory conditions and field conditions other than Indian.

The objective No. 1 demands the assessment of the reasoning patterns of the students before attempting at reorganising the curriculum frame. This is done by posing problems to the students which demand them to manifest the reasoning patterns. This assessment may affect the

the development of these reasoning patterns because the students who are exposed to these tasks may be triggered to mentally operate in a similar fashion. Since there are two possible sources of influence on the reasoning patterns, i.e., the treatment and the pre-assessment, there could be a possible joint effect of the two influences. The following four hypotheses are added alongwith the above two.

3. There is no difference in the combinatorial reasoning of students, who have been assessed through tasks which demand the use of such a reasoning pattern, and those who have not been assessed through such tasks.

4. There is no difference in the 'controlling of variables' of students, who have been assessed through tasks which demand the use of such a reasoning pattern, and those who have not been assessed through such tasks.

5. There is no difference in the 'combinatorial reasoning' of students, who have been pre-assessed on the same reasoning pattern and who have undergone the treatment, and who have not been pre-assessed and not undergone the treatment; and those who have not been pre-assessed and who have undergone treatment, and those who have been pre-assessed but not undergone the treatment.

6. There is no difference in the 'controlling of variables' of students, who have been pre-assessed on the same reasoning and who have undergone the treatment, and who have not been pre-assessed and not undergone the treatment; and those who have not been

pre-assessed and who have undergone treatment, and those who have been pre-assessed but not undergone the treatment.

6.5 The Design of the Study

The design should be able to accommodate the study of the following: 1) the effect of reorganising the prescribed curriculum frame on the reasoning patterns in comparison to the existing curriculum frame, 2) the effect of pre-assessment on the development of these reasoning patterns and 3) the interraction between the treatment and the pre-assessment. This problem may be examined through what is called a Solomon Four Group Design. The design is as follows:

Group 1	R	O_1	X	O_2
Group 2	R	O_3	.	O_4
Group 3	R		X	O_5
Group 4	R			O_6

where R is random assignment, X is experimental treatment and O_1 to O_6 are observations. Randomisation in the present study is not carried out by pooling all the units of the sample and allotting them to the four groups; but, four clusters (belonging to two different academic years) are taken from an institution which does not have any specific criterion for the allotment of students into each division.

6.6 Sample

The sample of the study comprises of four groups of students of grade IX of an English medium school in Baroda. The total number of students in the four groups is 204. The number of students in the four groups are as follows: Group 1 (N_1 = 50), Group 2 (N_2 = 52), Group 3 (N_3 = 52) and Group 4 (N_4 = 50). Two of these groups belong to the academic year 1981-'82 and the other two of the academic year 1982-'83. Only 6% of the sample speak English with peers and at home. The rest of the sample speak Gujarati, Marati or Hindi with peers and at home. The parental occupation of 61% of the sample is business and the rest are doing office jobs. The average age of the sample is fourteen years and eight months. The four groups are matched on two external criteria viz., 1) age and 2) intelligence as measured through Ravens Standard Progressive Matrices.

6.7 Tools and Techniques of Data Collection

The tools and techniques used in the present study are 1) clinical interview 2) an observation schedule for science instruction called System of Observation of Cognitive Processes in Science Instruction (SOCOPSI) and 3) unstructured interviews. In order to assess the level of reasoning of students the clinical interview technique gives more valid

information when compared to testing or pure observation. In a clinical interview the interviewer asks questions to a child, listens, observes, makes a hypothesis about the interviewees conceptual ability, and proceeds to ask more questions based on the hypothesis he has formed. The interviewer uses probing questions to get at underlying reasoning, encourages the child to test predictions and verify answers. In order to assess the level of reasoning of children with the above mentioned technique needs carefully planned tasks or problems. The study demands the assessment of two reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables'. Four tasks to assess each reasoning pattern is developed. Two of these tasks are used for pre-assessment and the other two for post-assessment. The four tasks used to assess the combinatorial reasoning are 1) Fun house puzzle, 2) Coloured chemicals, 3) Hockey player puzzle, and 4) Electrical switching system. The tasks used to assess the 'controlling of variables' are 1) Photosynthesis problem, 2) Pendulum, 3) Growth rate of plants, and 4) Falling bodies on an inclined plane. All these eight tasks were tried out on twentyfour IX grade students to establish the reliability of the scoring procedures and to establish the equivalence of the four tasks assessing one reasoning pattern.

The observation schedule used in this study is called

the "System of Observation of Cognitive Processes in Science Instruction" (SOCOPSI). The SOCOPSI gives a qualitative description of a classroom instructional process. It has two major dimensions viz., the behavioural dimension and the process dimension. Teacher and pupil initiated activities are coded separately into instructional events. Several such instructional events put together form an instructional episode based on the content point being discussed. The episodes can be categorised into different instructional patterns depending on the level of cognitive processes involved in the instruction.

Unstructured interview was used in the present investigation for three purposes. One, to probe into the reasons behind the non participation of students in the classroom activities. Two, to collect data regarding the planning of activities by the regular teacher of the school who was teaching the control groups. Three, to collect data regarding the admission procedure adopted by the school from the Principal. The main difference between the unstructured interview and the clinical interview is that in the former the investigator does not frame any hypothesis on the responses of the interviewee whereas in the latter the investigator (interviewer) frames a certain set of hypotheses on the responses of the interviewee and test against the actual responses.

6.8 The Experiment

Among the four groups mentioned in the design of the study group 1 and group 2 are pre-assessed using four tasks (two each for assessing two reasoning patterns). The assessment was made using clinical interview technique. The tasks used to assess the combinatorial reasoning are 1) fun house puzzle and 2) coloured chemicals, and for controlling of variables the tasks used are 1) photosynthesis puzzle and 2) pendulum task. The pre-assessment shows that none of the students operate at the formal level (III B). A vast majority of the students (67% in the combinatorial reasoning and 77% in the controlling of variables) operate at the concrete operational level (II A). Only 2 to 6% of the students show early formal reasoning. Objective No. 1 of the study is realised through this assessment procedure.

The curriculum analysis and reframing demand concretising of the formal concepts since the students are operating at the concrete level. The analysis of the prescribed curriculum indicate that most of the concepts dealt with demand formal operational structures on the part of the learners to assimilate. Also, dealing with the chemical and physical properties of elements as separate units leave a lot of gaps in the curriculum structure. The students should be able to interlink the relationship

between the preparation of one element with the property of another. The curriculum frame should be able to highlight such interrelationships among the elements. Based on these lines the whole curriculum is reorganised, thus realising objective no. 2 of the study. The dynamism of the curriculum frame lies on the instructional model through which it is presented to the learners. A model of instruction which incorporates a guided inquiry approach. The experimental group students (group 1 and group 3 of the design) were taught through such an instructional model for a semester (six months). The number of sessions engaged in these two groups were forty seven and forty eight respectively. The students of the control groups (group 2 and group 4 of the design) were taught by the regular teacher of the school. The teaching was based on the prescribed curriculum frame. The number of sessions engaged by the teacher were fifty and fifty two respectively to these two sections. Six sample lessons of both the experimental and control groups are observed using the SOCOPST.

The levels of reasoning (combinatorial reasoning and controlling of variables) of all the students, belonging to both the control and experimental groups, were assessed at the end of the respective semesters. The assessment was made using the clinical interview technique. The tasks used to

assess the combinatorial reasoning are 1) hockey player puzzle and 2) electrical switching system, and the tasks used to assess controlling of variables are 1) rate of growth of plants and 2) falling bodies on an inclined plane.

6.9 Analysis of Data

The data gathered through the experiment are subjected to qualitative and quantitative analyses. The improvement in the reasoning patterns (combinatorial reasoning and controlling of variables) in the control and experimental groups are compared. This comparison is made on the differences between the pre and post-assessments of group 1 and group 2. For a statistical analysis, the levels of reasoning are converted into scores; concrete operational reasoning (II A) is given a score of 1, transitional state (II B) is given a score of 2, early formal reasoning (III A) is given a score of 3, and formal operational reasoning (III B) is given a score of 4. The scale thus formed is assumed to be of interval scale. The 't' test is applied on the following four pairs of observations i.e., O_2 and O_1, O_2 and O_4, O_5 and O_6, and O_5 and O_3 to test the effect of the experimental treatment. Two way analysis of variance is applied on the post-assessment observations O_2, O_4, O_5 and O_6 to test the effect of the experimental treatment,

pre-assessment and the interaction between the treatment and pre-assessement.

6.10 Major Findings of the Study

The major findings of the study can be summarised as follows.

1. The reorganising of the prescribed curriculum frame and executing it through a dynamic model of instruction has positively influenced the 'combinatorial reasoning' of students when compared to those students who have undergone the normal classroom teaching based on the prescribed curriculum frame.

2. The pre-assessment of the 'combinatorial reasoning' of students through tasks have no significant effect on the same reasoning pattern.

3. There is no significant interaction between the experimental treatment and the pre-assessment on the 'combinatorial reasoning' of students.

4. The reorganising of the prescribed curriculum frame and executing it through a dynamic model of instruction has positively influenced the 'controlling of variables' of students when compared to those students who have undergone the normal classroom

teaching based on the prescribed curriculum frame.

5. The pre-assessment of the 'controlling of variables' of students through tasks have no significant effect on the same reasoning pattern.

6. There is no significant interaction between the experimental treatment and the pre-assessment on the 'controlling of variables' of students.

7. History and maturation have no significant effect on both the reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables'.

6.11 Suggestions for Further Research

The present study attempted at accelerating the reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables', through actual classroom instruction by reorganising the chemistry portion of the prescribed science curriculum. The reorganisation is based on 1) the prior conceptual structure of the learners, 2) the logical reasoning patterns the learners are capable of manifesting based on their logico-mathematical structures, and 3) the conceptual structure of the discipline. Deriving implications from the present study the following suggestions are discussed for future research.

1. Though the present study suggests that acceleration is possible it cannot be taken as conclusive evidence from this single attempt. A similar reorganisation of the Physics and Biology portions of the prescribed curriculum frame, and teaching it through the model of instruction used in the present study and studying the effect on the reasoning patterns would give further evidence on the merit of the instructional model.

2. The results of the present study suggest that a guided inquiry approach is better than a didactic approach in accelerating the logical reasoning. This cannot be taken as conclusive evidence because both these approaches were based on two different curriculum frames, i.e., the reorganised one and the prescribed one. This calls for a comparative study of both the approaches to instruction based on the reorganised curriculum frame.

3. The initial assessments of the reasoning patterns of grade IX students reveal that more than 70% of the students operate at the concrete level. In such a situation one can hypothesise that individualised instruction may be more effective in accelerating the logical reasoning. Or it may also be hypothesised that individual instruction coupled with group instruction might accelerate the reasoning patterns than by either one mode of instruction. These hypotheses may be put to test under laboratory conditions and then under field conditions.

4. The analyses of the data obtained through the present investigation suggest that students in the transitional state have gained better than the concrete operational

students. The differential effect of concrete and abstract instructional experiences on the acceleration of the reasoning patterns is an unanswered question. It may be hypothesised that concrete learners may gain better from concrete experiences and formal learners may gain better from abstract learning experiences.

5. The formal operational stage is the most complex among the stages of development in the Piagetian theoretical framework. Among the reasoning patterns that constitute this complex structure only 'combinatorial reasoning' and 'controlling of variables' have been assessed and accelerated in the present study. The logical operations of multiple classification, seriation, logical multiplication, proportional thinking, probability and correlational thinking may be used for assessing the formal structure and ~~depending~~ depending on the content being taught in an instruct instructional situation, the acceleration of suitable logical operations may be attempted.

6. The assessment of the two reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables' have shown differences in the levels of development. That is, all students who have shown early formal or formal operational reasoning in 'combinatorial reasoning' have not shown similar reasoning ability in 'controlling of variables'. Such a difference is termed as 'horizontal décalage' in the Piagetian theoretical framework. The assessment of other reasoning patterns that constitute the formal structure among the secondary students, and studying their interrelationship would aid the curriculum reorganisation at the secondary level. This is of

importance because the secondary school students are in a transitional state from concrete to formal operational stage and the development of formal structures are necessary for the assimilation of abstract concepts dealt with in the curriculum prescribed for the grades.

7. In the present study acceleration of formal reasoning patterns have been attempted at grade IX. Similar studies may be taken up at grades VII and VIII, where students show signs of transition. Attempts at accelerating the reasoning patterns at these grade levels may emphasise more on the manipulation of objects than the manipulation of ideas for the construction of cognitive structures.

8. The influence of language (medium of instruction and mother tongue) on the development of cognitive structures need further investigation. The experiences of the investigator during the clinical interviews in the present study, indicate that students think, comprehend and communicate better in the language they speak with peers than the medium of instruction, here, English. Whether teaching through an alien language would hinder the cognitive development is an unanswered question? Similarly, the relative merit of mother tongue and English in the development of cognitive structures need further investigation.

9. The relationship among other personality variables like affect attributes on the cognitive development has not been studied in the present investigation. The theory suggests that the affective and cognitive development are not only parallel, but influence each

other. There is, however, little empirical evidence on the interrelationship between emotional and cognitive development. Certain questions that can be taken up for further investigation in this field are:
a) whether the development in reasoning affects the attitude of students? and b) does scientific interest aids the development of cognitive structures?

10. The present study has attempted the acceleration of reasoning in a given urban context. Replication of similar studies under varied socio-cultural contexts would give further evidence on the hunch that the reorganising of the curriculum frame can influence the cognitive development of the students.

APPENDIX A

Raw scores of RPM and age of the sample, and the calculations of Analysis of Variance.

Raw scores (RPM) of the sample.

Sr. No.	Group 1 N_1=50	Group 2 N_2=52	Group 3 N_3=52	Group 4 N_4=50
1.	56	50	43	20
2.	54	38	49	21
3.	53	47	48	44
4.	54	53	47	50
5.	43	51	54	57
6.	54	52	46	49
7.	50	31	49	24
8.	41	47	46	47
9.	52	42	40	11
10.	52	50	41	50
11.	55	38	47	37
12.	43	42	40	55
13.	40	49	40	49
14.	34	52	41	54
15.	43	47	52	45
16.	53	17	48	46
17.	43	48	46	47
18.	52	42	49	40
19.	51	44	44	37
20.	50	54	47	50
21.	51	46	47	49
22.	34	49	51	30
23.	50	53	45	10
24.	51	51	34	15
25.	13	46	51	47
26.	47	50	49	12
27.	15	49	50	51
28.	9	51	47	50
29.	30	34	51	34
30.	49	45	53	51
31.	49	51	49	50
32.	37	47	46	51
33.	40	48	53	52
34.	47	42	46	43
35.	45	49	43	53
36.	48	46	48	43
37.	54	48	17	34
38.	49	51	47	40
39.	55	41	52	43
40.	37	40	48	55
41.	50	39	43	52

Sr. No.	Group 1 $N_1=50$	Group 2 $N_2=52$	Group 3 $N_3=52$	Group 4 $N_4=50$
42.	11	47	37	53
43.	47	41	50	42
44.	24	40	43	50
45.	49	45	47	54
46.	57	49	31	43
47.	49	46	52	54
48.	45	54	52	53
49.	21	47	53	54
50.	21	48	47	55
51.	..	50	39	..
52.	..	42	49	..
Total	2155	2379	2387	2156

Calculation of sum of squares

Step 1 Correction Term $= \frac{(9077)^2}{204} = 403882$

Step 2 Total sum of squares $= 424197 - 403882 = 20315$

Step 3 Between Mean sum of squares $\Big\} = \frac{(2155)^2}{50} + \frac{(2379)^2}{52} + \frac{(2387)^2}{52}$

$+ \frac{(2156)^2}{50} - 403882$

$= 376.95$

Step 4 Within sum of squares $\Big\} =$ Total SS – Between SS

$= 20315 - 376.95$

$= 19938.05$

Age (in years) of the sample

Sr. No.	Group 1 $N_1=50$	Group 2 $N_2=52$	Group 3 $N_3=52$	Group 4 $N_4=50$
1.	14	16.2	15.5	15.4
2.	13.2	15.9	13.9	15.8
3.	13.1	16.3	15.5	16.3
4.	14.5	15.9	14.3	14.9
5.	15.3	16.7	14.3	15.9
6.	14.3	16.9	15.1	14.7
7.	14	13.9	15.8	15
8.	15	15	14.4	15.4
9.	14.3	15.6	15	14.1
10.	14.6	16.7	14.4	13.9
11.	14	15.1	13.9	15.6
12.	15.8	14.1	14.3	15
13.	15.9	14.4	14	14
14.	14.4	15.3	16.3	14.5
15.	13.6	15.4	15	13.5
16.	14.9	14.1	14.3	15.9
17.	14.5	15.1	14	14
18.	14.2	15.2	13.9	16.1
19.	13.3	15.1	15	13.6
20.	15.3	14	15.6	14
21.	14.9	13.7	14.4	15.9
22.	13.9	13.8	14.3	16.1
23.	13.8	14.6	14.1	14.3
24.	15.3	13.9	15	15.3
25.	15.4	14.1	15.1	15.4
26.	14.4	15.5	13.4	13.4
27.	15	13.6	14.9	13.7
28.	15	13.4	15.7	15
29.	15	15.9	14.4	15.9
30.	15.4	14.2	13.7	14.9
31.	16	14.9	14.4	16
32.	16.9	15.5	15.6	14.4
33.	14.9	13.7	13.8	14.3
34.	15.2	14.6	14.1	15.6
35.	15.7	14.9	13.9	14.5
36.	14.8	15	13.9	15.5
37.	13.1	15.9	15.9	13.6
38.	13.9	14.8	16.5	14.8
39.	14.9	14.4	14.3	13.9
40.	13.9	14.7	13.5	14.5
41.	13.9	15.1	13.9	14.3
42.	14.2	14.9	14.2	14

Sr. No.	Group 1 $N_1=50$	Group 2 $N_2=52$	Group 3 $N_3=52$	Group 4 $N_4=50$
43.	15.9	15	13.9	14.9
44.	14.6	14.9	14.1	13.9
45.	14	13.6	15.8	15
46.	14.4	13.9	13.6	13.4
47.	15.3	14.9	15	15.9
48.	14.7	15.9	14.7	13.9
49.	14.4	14.8	13.8	14.4
50.	16.6	15.5	14.5	15.5
51.	..	14.1	15.4	..
52.	..	14.1	15.9	..
Total	733.6	775.7	760.2	739.8

Calculation of sum of squares

Step 1 Correction Term $= \frac{(3009.3)^2}{204} = 44391.6$

Step 2 Total sum of squares $= 44536.7 - 44391.6$

$= 145.1$

Step 3 Between sum of squares $= \frac{(733.6)^2}{50} + \frac{(775.7)^2}{52} + \frac{(760.2)^2}{52}$

$\frac{(739.8)^2}{50} - 44391.6$

$= 2.75$

Step 4 Within sum of squares $=$ Total SS $-$ Between SS

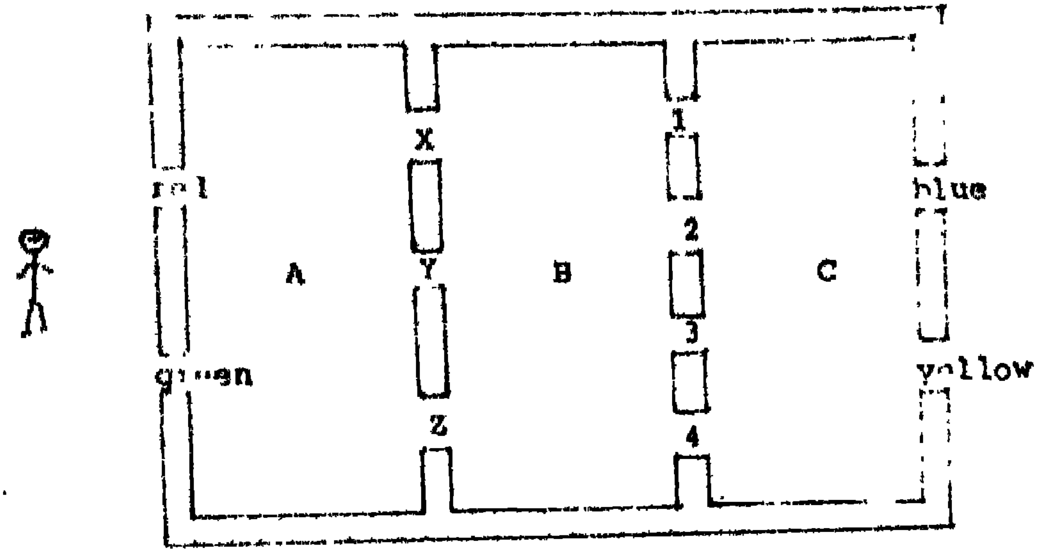
$= 145.1 - 2.75$

$= 142.35$

APPENDIX B

Tasks for assessing the reasoning patterns and the criteria for assessment

Task 1: Fun House Puzzle* (combinatorial reasoning)



The above given plan of a three room house is given to the interviewee. The interviewer then enters into a dialogue with the interviewee explaining that the figure shows the diagram of a house having three rooms A, B and C. To enter the room A there are two doors coloured red and green. One can enter through any one of the doors. From the first to the second room, there are three doors marked X, Y and Z. From the second to the third room, there are four doors marked 1, 2, 3, and 4. From the third room to go out there are two doors coloured blue and yellow. If one has to pass through the three rooms, one has to pass through four doors. For example, pointing at the figure outside the house, the interviewer shows that one has to pass through the red door, A door, door numbered 1 and the blue door to pass through the three rooms and go out.

Then the interviewer asks the interviewee to show all the other possible ways of passing through the three rooms. The interviewee is supplied with a paper and pencil to write all the possible ways i.e., all possible four door paths as given in the example.

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* Adapted from Walker et. al., (1979) p.212.

Criteria for assessment

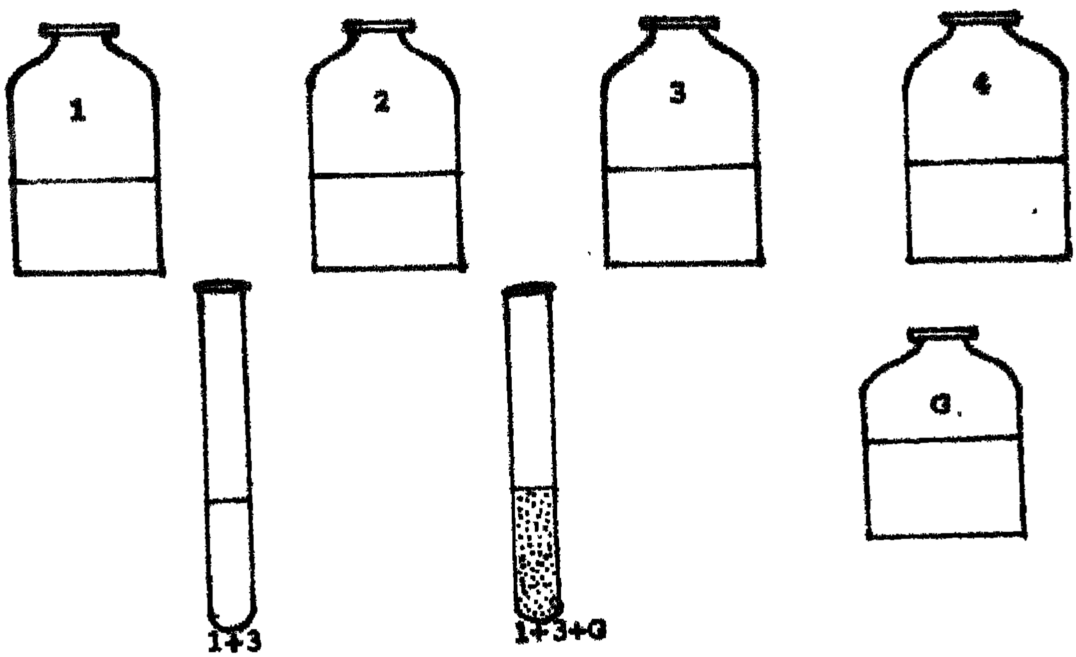
II A - The subject who simply attempts combinations of a single set of doors from among the four sets viz., red and green; X, Y and Z; 1, 2, 3 and 4; and blue and yellow. That is, one who finds more than one path but less than five.

II B - This substage is characterised by one who goes about solving the problem with the basic combinations and with the addition of nxn and n x n x n combinations. That is, finding out more than six paths and less than 25.

III A - This substage is characterised by n X n, n X n X n, and n X n X n X n combinations. That is, finding out more than twenty six paths without proper explanation of the combinatorial system.

III B - This substage is characterised by all possible combinations i.e., finding out all the forty eight paths in a systematic way and explaining how it was found.

Task II: Coloured Chemicals* (combinatorial reasoning)



* Refer Inhelder and Piaget, (1958) Pp.107-108

The interviewee is given four similar bottles containing colourless liquids which are perceptually identical. They are numbered: 1 (dilute sulphuric acid); 2 (water); 3 (oxygenated water); and 4 (thiosulphate solution). Another bottle with a colourless liquid with a dropper is added to the above four. This is labelled G. The interviewee is shown a test tube containing a colourless liquid. The interviewer tells that the liquid is taken from one of the four bottles or combinations of two or more from the four bottles. The interviewer then adds a few drops of the liquid G to the test tube. The colour of the liquid changes to yellow. The interviewee is then asked to do various experiments to produce the yellow colour. They are supplied with test tubes (washed and cleaned). Detailed observations are made on the combinations tried out by the interviewee. If the interviewee stops after a couple of trials, he is persuaded to try all possible combinations.

Criteria for assessment**

II A - The subject who simply attempts combinations of a single liquid with G or all four with G, without any other combinations, is in substage II A. Any hypothesis formed will be quantitative (too much water or too little water) dealing with only serial ordering or correspondence. If the colour is achieved, it will be fortuitous and the colour will be attributed to a single liquid rather than a combination.

II B - This substage is characterised by the same basic reactions, with the addition of some n X n combinations with G or n X n X n combinations with G. At this substage the subject will not continue to experiment without reasonable prompting.

III A - The two innovations that appear at this substage are the introduction of a systematic method in the use of n X n combinations and an understanding that the colour is the resultant of a combination rather than coming from one of the liquids. A subject at this substage, when producing a colour producing combination, does not stop there, but goes on. He tests other combinations.

III B - The difference between the substage II B and the earlier one is only of degree. In this substage the combinations and proofs are organised more in a systematic fashion with the experiment organised from the start with the intent to find the proof.

** Refer Renner et. al. (1976)

Task III: Photosynthesis Puzzle£ (controlling of variables)

The interviewer supplies the interviewee data regarding five experiments conducted under different conditions. The different conditions and the results of the experiment are given in the following table.

Container	Plant	Part of the plant	Light colour	Temp. °C	CO_2 remaining
1	Tulasi	leaf	blue	10	200
2	Balsam	leaf	purple	23	50
3	Tulasi	root	red	18	300
4	Balsam	stem	red	23	400
5	Tulasi	leaf	blue	23	150

Initial amount of carbon dioxide in all the jars is 250 units and all jars are kept in these conditions for two days.

The interviewer describes the experiments by telling that the jars are kept under different conditions for two days. He then asks the interviewee to explain the five experiments in his own language. This is to ensure that the interviewee has understood the conduct of the experiment. Taking cues from the talks of the interviewee and using the same words, the interviewer asks the following question. On the basis of the data given in the table, which two jars or containers will you compare to find out the amount of carbon dioxide absorbed per day at two different temperatures. It is implied in the question that the other conditions have to be the same. But, this clue is not made obvious to the interviewee.

Criteria for assessment

II A - The subject who simply answers by comparing any two jars kept at two different temperatures or the same temperature with improper explanations.

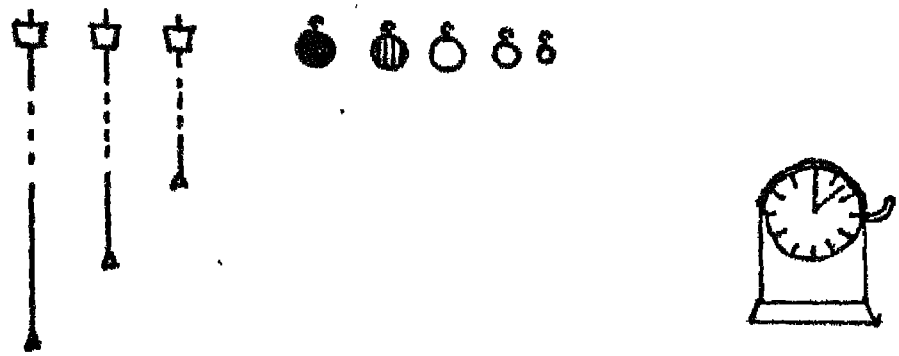
II B - This substage is characterised by the comparison of two jars kept at two different temperatures and controlling any one or two of the other three sets of variables viz., plant, parts of the plant and colour of light. The controlling is expressed through proper explanations.

III A - This substage is characterised by the subject who compares two jars kept at two different temperatures and controlling three sets of variables, but not supporting it with proper explanation or who changes his line of argument on probing further.

£ Adapted from Wright (1979)

III B - A subject who compares two jars at different temperatures by controlling all the other variables and giving valid explanations for the same.

Task IV: Pendulum# (controlling of variables)



The interviewer gives three threads of different length to the interviewee, a stand to fix the thread, and a set of bobs. The bobs are of different sizes and weights. Among the five bobs, three are large (their volume is the same, but the material is different and so the weights are different), one a lead, the second brass, and the third an aluminium bob. A set of two more aluminium bobs are given to the interviewee. They are of varying volume. The three threads have a hook each tied at one end and the bobs can be hung on these hooks. The interviewer then asks the interviewee to make different pendulums using one thread and a bob at a time, and make them swing each time. He is supplied with a stop watch. The interviewee is asked to answer the following question after conducting various experiments. Which among the factors viz., length of the string, mass of the bob, volume of the bob, and the height at which the bob is released affect the period of motion of the pendulum? In other words, what factor makes the bob go up and down slow or fast?

The activities carried out by the interviewee is noted in detail by the interviewer.

Criteria foe assessment

II A - The subject who simply cannot control any of the variables. The fairly obvious variables are: 1) the weight of the bob, 2) the length of the string, 3) the height of the dropping point, and 4) the

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Refer Inhelder and Piaget, (1958) Pp.68-69

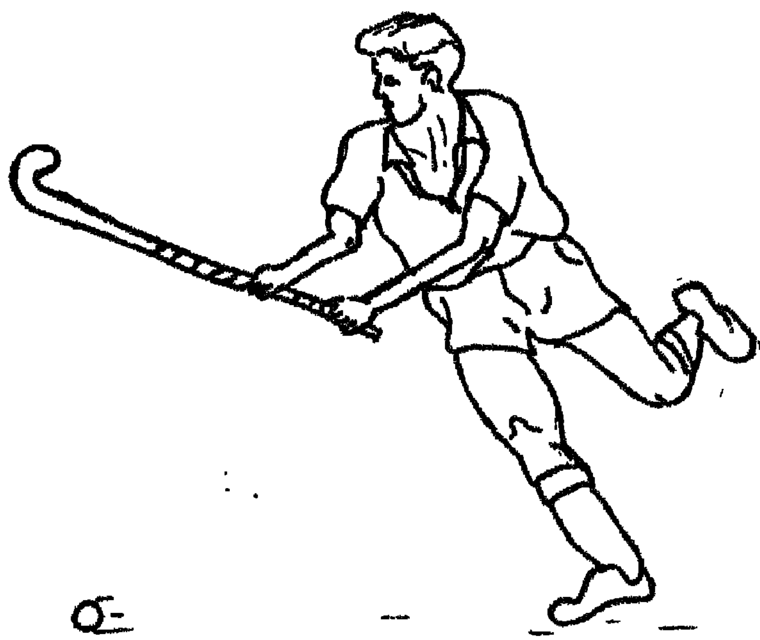
magnitude of push given to the bob.

II B – This substage is characterised by controlling one or two among the obvious variables except the relevant variable, i.e., the length of the string.

III A – This substage is characterised by controlling the variables one by one keeping others constant, but, fails to explain his action.

III B – This substage is characterised by controlling the variables systematically and giving a proper explanation for his actions.

Task V: Hockey Player Puzzle* (combinatorial reasoning)



The above figure is shown to the interviewee and he is supplied with coloured paper cuttings of sets of jerseys, shorts/skirts, stockings and boots. That is, jerseys of four colours viz., Orange, Purple, Green and Yellow; shorts/skirts of three colours viz., Red, Lemon and Violet; stockings of two colours viz., Cocky and Ivory; and boots of two colours viz., Black and White. The interviewer then places one set of jersey, shorts/skirts, stockings and boots on the figure and explains to the interviewee how the set forms one way of putting on or wearing the playing gear. Then the interviewer

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* Developed by the investigator.

asks the interviewee to try and find the different possible ways in which the player can wear the sets of gear given to them.

The interviewer then makes detailed observations regarding the way the interviewee goes about solving the puzzle.

Criteria of assessment

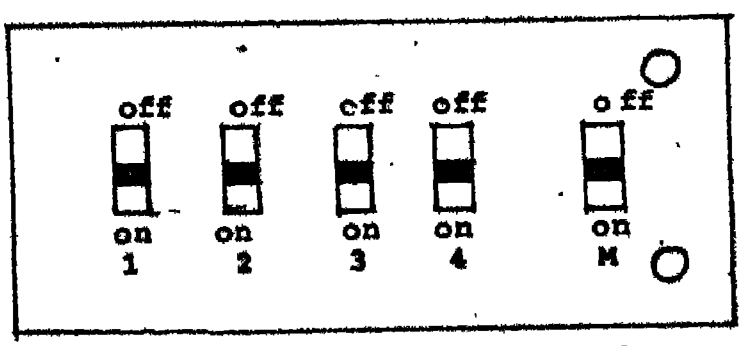
II A – The subject who attempts only a single set of gear from among the different sets possible. That is, one who finds more than two ways of wearing the gear and less than five ways.

II B – This substage is characterised by the same basic combination with an addition of n X n and n X n X n combinations. That is, finding more than six different ways of wearing the gear and less than twenty five ways.

III A – This substage is characterised by n X n combinations, n X n X n, and n X n X n X n combinations. That is, finding out more than twenty five ways of wearing the gear without proper explanation of the combinatorial system.

III B – This substage is characterised by all possible combinations. That is, finding out all forty eight possible ways of wearing the gear and explaining it logically.

Task VI: Electrical Switching System* (combinatorial reasoning)



* Developed by the investigator.

This switching system consists of five switches marked 1, 2, 3, 4 and M. The switches are connected to a dry cell and then to a light emitting diode (LED). The switches are connected in such a way that the combination of switches '1', '3' and 'M' in the 'on' position, the cell and the LED comes in series and the LED emits light. The switch '2' is not connected to the circuit at all. Switch '4' is connected in such a way that, when it is in the 'on' position the circuit to the LED is broken. Therefore, under two combinations of the switches in the 'on' position the LED gives out light. They are: 1) '1', '3' and 'M', and 2) '1', '2', '3' and 'M'.

The interviewer asks the interviewee to try all possible combinations to light the LED. The interviewee is specifically asked to try all possible combinations, even if they could make the LED give out light once.

Criteria of assessment

II A - The subject who simply attempts combinations of a single switch in the 'on' position with 'M' or all four switches 'on' with 'M'. A subject in this sub-stage will not try any other possible combination.

II B - This substage is characterised by the same basic combinations as given in II A with the addition of n X n combinations. That is, more than five combinations but less than ten.

III A - This substage is characterised by n X n and n X n X n combinations, and an understanding that the light is the result of a combination of switches in the 'on' position and not from any one of the switches. A subject at this substage, when finding a light producing combination, does not stop there, but goes on to test other combinations. The subject may not be in a position to give full explanation of the combinatorial system.

III B - This substage is characterised by the subject who goes about finding the combinations and proofs in a more organised manner. The subject starts with the intention of finding the proof.

Task VII: Growth Rate of Plants[@@] (controlling of variables)

Pots	Type of soil	Manure	Mugs of water/day	Light Condition	Growth of plant
1	Sandy	X	1	shade	14
2	Sandy	Y	3	sun	10
3	Clayey	Z	2	shade	8
4	Mixed	Z	3	sun	12
5	Sandy	X	2	shade	16

The student is given detailed information regarding experiments conducted to find the rate of growth of bean plants. He is told that five mud pots are taken of equal size and are filled with sandy, clayey and mixed soil as given in the table. Three different types of manure are added to the pots as given in the table. Also, the student is supplied with details regarding the conditions under which the pots are kept for a period of two weeks. At each stage of narrating the problem to the interviewee, he is asked to repeat the experimental conditions. This is done to ensure that the interviewee has perceived the problem as the interviewer wants him to.

The interviewee is then asked the following question. By comparing which pots can one study the effect of watering on the growth rate of the plants?

Criteria of assessment

II A – The subject who simply compares any two pots kept at two different conditions without caring to control even a single set of variables.

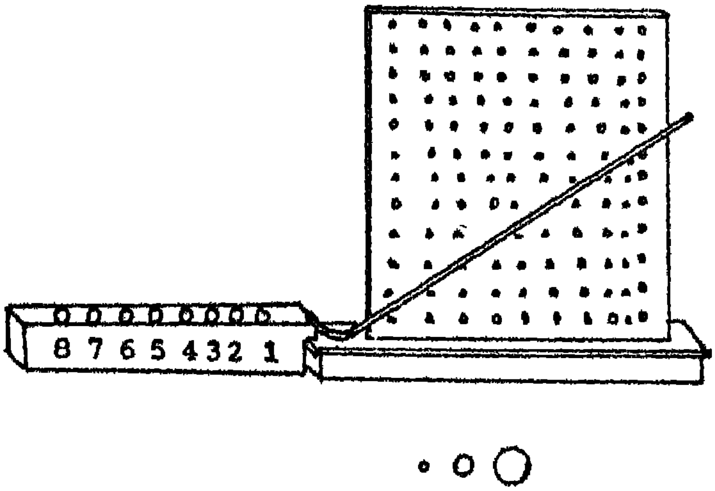
II B – This substage is characterised by the comparison of two pots to which different amounts of water has been added per day, but not controlling other sets of variables, viz., type of soil, manure and the light condition.

III A – This substage is characterised by the subject who compares pots kept under different light conditions by controlling all other sets of variables with improper explanations.

III B – The subject who compares the pots to which different amounts of water is added per day, and controlling all other variables. Also, the subject is in a position to offer proper explanation for his comparison.

@@ Adapted from Menon (1985).

Task VIII: Falling Bodies on an Inclined Plane* (controlling of variables)



The experimental apparatus consists of a plane adjustable to various angles of incline. A ball can be rolled down the plane; it bounds when it hits a springboard at the base. The problem is to find the relationship between height of the point from which the ball is released and the length of its bound. To study the relationship the interviewee is given steel balls of three different sizes. Since the material with which the ball is made remains the same their weight also changes because of the difference in the volume.

The inclined plane can be raised or lowered by moving the peg on which it rests to different holes in the board. These also serve as an index for measuring height. Balls of varying sizes are released at different heights on this plane, hit a board at the bottom, bound in parabolic curves, and come to rest in one of the compartments (numbered 1 to 8). These are the interviewee's index to the length of the bound.

Criteria of assessment

II A- The fairly obvious variables are; size of the bob, mass of the bob, height from which the bob is rolled along the inclined plane and the distance from the lowest point of the inclined plane. This substage is characterised by the subject who does not control any of these variables.

II B- This substage is characterised by controlling one or

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* Refer Inhelder and Piaget (1958) Pp.80-81.

two among the obvious variables except the relavent variable i.e., height of the point from which the bob is released.

III A -This substage is characterised by controlling all the obvious variables including the relavent one, but, in an unsystematic fashion and giving improper explanations.

III B- This substage is characterised by controlling the variables one by one in a systematic manner and giving the right explanations.

APPENDIX C

Assessments of the reasoning patterns by three judges on the eight clinical interview tasks.

Sr. No.	Age*	Sex	Task I			Task II		
			B	A	S	B	A	S
1	14;0	F	II B	II B	II B	II B	II B	II B
2	13;9	M	II B	II B	II B	II B	II B	II B
3	13;10	M	II B	II B	II B	II B	II B	II B
4	13;5	M	II B	II B	II B	II B	II B	II B
5	13;1	M	II B	II B	II B	II B	II B	II B
6	13;4	F	II B	II B	II B	III A	III A	III A
7	15;6	M	II B	II B	II B	II A	II A	II A
8	14;2	F	II A	II A	II A	II B	II B	II B
9	13;2	F	II B	II B	II B	II B	II B	II B
10	13;1	F	II B	II B	II B	II A	II A	II A
11	13;11	F	II A	II A	II A	II A	II A	II A
12	12;4	M	III B	III B	III B	III B	III B	III A
13	15;1	M	II A	II A	II A	II B	II B	II B
14	13;4	F	II A	II A	II A	II A	II A	II A
15	13;6	F	II B	II B	II B	II A	II A	II A
16	13;9	M	II B	II B	II B	II A	II A	II A
17	14;4	F	II A	II A	II A	II B	II B	II B
18	13;2	F	II A	II B	II B	II B	II B	II B
19	13;4	F	II B	II B	II B	II B	II B	II A
20	13;5	M	II B	II B	II B	II B	II B	II B
21	12;4	M	II B	II B	II B	II B	II B	II B
22	12;9	M	II B	II B	II B	II B	II A	II B
23	14;8	M	II B	II B	II B	II B	II B	II B
24	14;8	M	III A	III A	III A	III A	III A	III A

*Age in years;months.

Task I - Fun House Puzzle.

Task II - Coloured Chemicals.

B - Judge 1

A - Judge 2

S - Judge 3

Sr. No.	Task III			Task IV			Task V		
	B	A	S	B	A	S	B	A	S
1	II A	II A	II A	II A	II A	II A	II B	II B	II B
2	II A	II A	II B	II A	II A	II A	II B	II B	II B
3	II A	II A	II A	II A	II A	II A	II B	II B	II B
4	II A	II B	II B	II B	II B	II B	II B	II B	II B
5	II A	II B	II B	II B	II B	III A	II B	II B	II B
6	II A	II A	II B	II A	II A	II A	II B	II B	II B
7	II A	II A	II A	II A	II A	II A	II B	II B	II B
8	II A	II A	II A	II B	II B	II B	II A	II A	II A
9	II A	II A	II A	II A	II A	II A	II B	II B	II B
10	II A	II A	II A	II A	II A	II A	II B	II B	II B
11	II A	II A	II A	II A	II A	II A	II A	II A	II A
12	II B	II B	III A	II B	III A	II B	III B	III B	III B
13	II A	II A	II A	II B	II A	II B	II A	II A	II A
14	II A	II A	II A	II A	II A	II A	II A	II A	II A
15	II A	II A	II A	II A	II A	II A	II B	II B	II B
16	II A	II A	II A	II B	II A	II A	II B	II A	II B
17	II A	II A	II A	II A	II A	II A	II A	II A	II A
18	II A	II A	II A	II A	II A	II A	II B	II B	II B
19	II A	II A	II A	II A	II A	II A	II B	II B	II B
20	II B	II B	II B	II B	II B	II B	II B	II B	II B
21	II B	II B	II B	II B	II B	II B	II B	II B	II B
22	II A	II A	II A	II A	II A	II A	II B	II B	II B
23	II A	II A	II A	II A	II A	II A	II A	II B	II B
24	II B	II B	II B	II B	II B	II B	III A	III A	III A

Task III - Photosynthesis
Task IV - Pendulum
Task V - Hockey player

B - Judge 1
A - Judge 2
S - Judge 3

Sr. No.	Task VI			Task VII			Task VIII		
	B	A	S	B	A	S	B	A	S
1	II B	II B	II B	II A	II A	II A	II A	II A	II A
2	II B	II B	II A	II A	II A	II A	II A	II A	II A
3	II B	II B	II B	II A	II A	II A	II A	II A	II A
4	II B	II B	II B	II B	II B	II A	II B	II B	II B
5	II B	II B	II B	II B	II B	II B	II B	II B	II B
6	III A	III A	III A	II A	II A	II A	II A	II A	II A
7	II A	II A	II A	II A	II A	II A	II A	II A	II A
8	II B	II B	II A	II A	II A	II A	II A	II B	II B
9	II B	II B	II B	II A	II A	II A	II A	II A	II A
10	II A	II A	II A	II A	II A	II A	II A	II A	II B
11	II A	II A	II A	II A	II A	II A	II A	II A	II A
12	III B	III B	III B	II B	III A	II B	II B	III A	II B
13	II B	II B	II B	II A	II A	II A	II B	II B	II B
14	II A	II A	II A	II A	II A	II A	II A	II A	II A
15	II A	II A	II A	II A	II A	II A	II A	II A	II A
16	II A	II B	II B	II A	II A	II A	II A	II A	II A
17	II B	II B	II B	II A	II A	II A	II A	II A	II A
18	II B	II B	II B	II A	II B	II A	II A	II A	II A
19	II A	II B	II B	II B	II B	II A	II A	II A	II A
20	II B	II B	II B	II B	II B	II B	II B	II B	II B
21	II B	II B	II B	II B	II B	II B	III A	II B	II B
22	II A	II A	II A	II A	II A	II A	II A	II A	II B
23	II B	II B	II B	II A	II A	II B	II A	II A	II A
24	III A	III A	III A	II B	II B	II B	II B	II B	II B

Task VI - Electrical Switching System

Task VII - Growth Rate of Plants

Task VIII - Falling Bodies on an Inclined Plane

B- Judge 1

A - Judge 2

S - Judge 3

APPENDIX D

Observation Schedule

System of Observation of Cognitive Processes (SOCOPSI)#

This system of classroom interaction observation has two dimensions viz., the Behaviour Dimension and the Process Dimension. A relevant instructional behaviour can be classified into one of the seven categories given in this system. Each behaviour exhibited by the Teacher or the Student has an underlying process. This process can be included in one among the nine categories given in the system. The categories in these two dimensions and their definitions are given below:

Categories and their definitions

I Behaviour: is meant to be an overt, observable, verbal or non verbal act on the part of the teacher or the student, classifiable into distinct categories. Here, only those behaviours having an underlying cognitive process dimension are considered.

1. Exposition: states, lectures, narrates, explains, describes, enumerates, etc.
2. Questioning: interrogates, calls for explanations; statements, justifications, etc.
3. Directing: instructs to carry out specific acts.
4. Giving Feedback: an act in response to and reinforcing another act.
5. Guiding/Supervising/Listening/Watching: All the above are passive behaviours. Guiding/Supervising is when the actor passively oversees a certain activity done by another/others. Listening/Watching is a passive activity of receiving.
6. Performing/Observing: both these are active behaviours. Performing means manipulating an object physically, e.g., writing. Observing means specifically looking for/at events or objects.
7. Misellaneous: Any behaviour that has not been included in the above categories; but, relevant in understanding the mental processes of a behaviour.

II Process: is the cognitive activity underlying a behaviour. It forms the intentions behind manifesting a behaviour, and as such can be deduced from the

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Developed by Menon et. al. (1981)

occurance of the behaviour in a particular context.

1. Giving information: Retrieving facts or accepted data from one's reportoire of experience and presenting them. Reporoducing facts, data from verbal or pictorial sources. Recognising an object or event based on one's reportoire of experience and presenting facts, data concerning them.

2. Seeking/receiving/gathering information: Active/passive reception of facts, data, etc. Seeking information means asking for information. Receiving information means a passive intake of information. Gathering information means collecting facts, data, etc., through observation, referring verbal or pictorial sources.

3. Calling for hypotheses/Posing a problem: Asking for identifying dependant and independant variables in a phenomenon and calling for possible causal relationships among them. Presenting incomplete information with a gap and asking for possible ways of bridging the gap. Presenting jumbled bits of information and asking for possible patterns of organising them.

4. Giving hypotheses: Identifying dependant and independant variables in a phenomenon and presenting possible relationships among them. Suggesting ways of bridging gaps among incomplete facts, data, etc. Suggesting alternative patterns of organising jumbled bits of information.

5. Testing/Evaluating/Judging hypotheses/Working out the problem: Deducing observable events from hypotheses. Planning/fabricating procedures of controlling relevant variables and observing. Making observations to verify hypotheses. Recalling and reconstructing past experiences to verify hypotheses. Trying out ways of bridging gaps among incomplete facts, data, etc. Trying out alternative patterns of organising jumbled bits of information.

6. Accepting/rejecting Hypotheses: Taking a hypothesis as confirmed, on the basis that testing procedures have been necessary and sufficient proof for its validity. Rejecting a hypothesis on the basis of insufficient proof.

7. Challenging hypothesis/information: Pointing out internal contradictions of a hypothesis. Pointing out factual errors. Pointing out contradictions in testing procedures. Pointing out insufficient basis of confirming a hypothesis.

8. Generalising/Delimiting hypothesis: Seeing a verified hypothesis in a wider context and determining the scope and extent of its applicability.

9. Summarising/Consolidating: Organising and taking stock of the various processes completed so far and draw relevant conclusions and ask further relevant questions. Highlighting the salient features of the various bits of information and organising them into a structure.

Recording a Classroom Instruction Using SOCOPSI

Recording using SOCOPSI is not done with a time interval. A teaching point or an 'instructional episode' is taken as the unit for coding and is coded within a square bracket. One 'instructional episode' comprises of several 'instructional events'. The teacher initiated events are recorded with the letter 'T' and student initiated events by 'S'. An event has two dimensions viz., the behavioural dimension and the process dimension. A recorder judges and then classifies the behaviour of the teacher or student into one of the seven categories. He records the number of the category next to the letter 'T' or 'S' as the case is. Based on the judged behaviour of the teacher or student initiated activity, the recorder infers the underlying process and identifies it among the nine process categories and records it. Therefore an instructional event is recorded with a letter and two numbers, the letter to represent the initiator and the numbers representing the two dimensions. A couple of illustrations are given below to illustrate the coding procedure. One, a teacher explaining/describing a teaching point is recorded as T_{11}. Two, a student asking a clarification on what the teacher spoke is recorded as S_{21}. Such a coding denotes an instructional event. An instructional event is differentiated from another with a (,) e.g., T_{11}, T_{21}. If two relevant instructional events take place simultaneously, then the recorder records it with an oblique sign e.g., T_{23}/T_{63}. Several such events put together forms an 'instructional episode'. And such an episode is bracketed using square brackets. There may be several such episodes in an instructional situation. Sometimes the entire duration of a class may have only one episode e.g. [T_{11}, T_{11}, T_{19}].

terns of Classroom Instruction

tern I: Narration Pattern

The teacher narrates an entire teaching point. He summarises and concludes the narration without attempting to make the students actively participate in the classroom instruction. The recordings may go like this: [T11, T11, T19]. Here, the whole content is treated at the information level.

tern II: Narration with aids Pattern

Here, the teacher covers an entire teaching point through his narration assisted by audio-visual aids including a demonstration. The recordings may go like this: [T11, T61, T11, T19]. The aids are used only to pass on an information i.e., no attempt is made to pose problems to the students.

ttern III: Narration with recall questions

In this pattern of instruction the teacher covers a teaching point through his narration, but intermittently asks questions to seek information thereby evaluating the students' immediate learning. The recordings may go like this: [T11, T22, S11 ; T11, T22, S11, T41/T42, S11] etc. Here again the treatment of content is at the information level.

ttern IV: Narration with aids and Recall questions

In this pattern the teacher covers a teaching point through his narration and with the help of aids and asking information level questions to seek clarifications from the students thereby evaluating the immediate learning. The recordings may go like this: [T11, T61, T22, S11, T41, T42, S11].

attern V: Process by-pass Pattern without aids.

Here, the teacher poses a problem calling for hypothetical solutions; the stdents give hypotheses; the teacher accepts it or rejects it; explains his reason for rejecting or accepting the hypothesis or hypotheses and concludes. The recordings may go like this: [T23, S14, T46, T11, T19]. The main difference in this pattern from the former four patterns is that the teacher calls for hypothesis from the student thereby 'kindling' their thought processes.

Pattern VI: Process by-pass Pattern with aids

Here, the teacher poses a problem, by recalling experiences, by the use of aids, calling for hypothetical solutions; the students give hypotheses; the teacher accepts or rejects it; explains the reason for accepting/rejecting the hypothesis or hypotheses and concludes. The recordings may go like this: [T63, S14, T46, T11, T19]. The main difference between Pattern V and this is that the teacher poses a problem with the use of aids or day to day experiences thereby attempting to 'kindle' the

thought process of students. Such a presentation of the problem may appeal as problems to the students rather than a prescriptive problem (as in the case of pattern V).

Pattern VII: Process Narration Pattern without aids

In this pattern the teacher, poses a problem calling for hypothetical solutions; then, gives possible alternate hypotheses; eliminates the unstable and internally contradictory ones, through logical arguments; tests the plausible hypotheses through arguments; accepts the validated solutions and fits into a large conceptual frame and concludes. A typical recording may go as follows: [T_{13}, T_{23}, T_{14}, T_{15}, T_{16}, T_{17}, T_{18}, T_{19}]. Here, the instructional episode is not at the information level but at the hypotheses testing level. This pattern does not attempt at ensuring the students' active participation.

Pattern VIII: Process Narration with Aids

In this pattern the teacher poses a problem with the help of aids or past/day to day experiences, calling for hypothetical solutions; then gives possible alternate solutions; eliminates the unstable and internally contradictory ones, through logical arguments; tests the plausible hypotheses with or without the help of aids; accpts the validated solutions and fits into a large conceptual frame and concludes. A typical recording may go as follows: [T_{62}, T_{23}, T_{14}, T_{15}, T_{16}, T_{17}, T_{18}, T_{19}] Like Pattern VII the instructional episode is at the hypothesis testing level and not at the information level. This pattern is a shade better than pattern VII to the extent that the problem is likely to appear as a 'problem' to the students since the problem posing phase of the episode is agumented with real or simulated experineces. The lacuna in this model is that an active participation on the part of the learners is not ensured.

Pattern IX: Process of Inquiry Pattern

Here, a conceptual background is prepared by the teacher through discussion or through the provision of concrete experiences which culminates in the identification of the problem. The teacher consciously creates the background of the problem keeping in view the total curriculum frame and the concept to be highlighted and also the level of abstraction which the stage of cognitive development of the students' allows. Once the problem emerges from the students the teacher calls for hypothetical solutions or the students themselves come out with hypothetical solutions. Comcomitantly the internally contradictory hypotheses are rejected by the students. Also, they reject the untestable hypotheses. The possible hypotheses are tested against actual observations or data based on earlier observations made by others. The tested hypotheses evoke further hunches

and the interaction proceeds in a cyclic manner; or it is integrated into the understanding of the phenomenon. A typical 'episode' may be recorded as follows: [T_{11}, T_{22}, S_{11}, T_{23}, S_{41}, T_{27}, T_{17}, S_{27}, S_{17}, S_{16}, S_{18}, S_{19}, T_{27}, S_{16}, S_{17}, S_{18}, T_{19}].

APPENDIX E

SAMPLE CLINICAL INTERVIEWS

Task I: Fun House Puzzle (combinatorial reasoning).

Interview with NDP: sex - male, age 13 years; 11 months.

After establishing rapport with the interviewee, a card containing the plan of a house having three rooms is given to the interviewee.

Interviewer: This is a plan of a house with three rooms A, B and C (pointing at the plan of the house). The rooms are connected by doors. Suppose you are standing here (pointing at the figure on the card), and you want to pass through the three rooms. To enter the first room there are two doors i.e., a red door and a green door. You can pass through any one of them. To enter the second room from the first, there are three doors. They are; door marked A, door marked B and the door marked C. You can pass through any one of them (pointing at the plan). To enter the third room from the second there are four doors. Door marked 1, door marked 2, door marked 3 and door marked 4. You can pass through any one of them. And, finally, to go out of room C there are two doors; a blue door, and an yellow door. You can pass through any one of them. To pass from here to here (pointing at the card) you have to pass through four doors and let us call it a four door path. Now, you explain to me what this four door path is.

NDP: I can pass through Red, X, 1 and blue. This is a path.

Interviewer: Now, can you tell me how many such four door paths are there? I mean, you have shown me one path. Are there other paths also?

NDP: Yes, there are (pointing at the card). I can pass through Green, Z, 4 and yellow.

Interviewer: Can you tell me how many such four door paths are there totally?

NDP: (looks around, no response).

Interviewer: If you want to write anything you can use this paper and pencil (pointing at them kept on the table).

NDP: No. (after a long pause takes the paper and starts writing).

Int: (after the interviewee has stopped writing) Have you completed?

NDP: Yes. There are four paths (pointing at what he has written).

Int: Please explain the four paths.

NDP: Red, X, 1, & blue; Red, Y, 2 & yellow; Green, Z, 3 & blue; and Green, Z, 4 and yellow.

Int: Can you pass through Green, X, 4 & yellow?

NDP: (after a pause) No.

Int: Why?

NDP: I have already passed through X.

Int: You have already passed through Z twice (pointing at what the interviewee has written).

NDP: Then, there are only two ways.

Int: But, you have written four?

NDP: Idont know, I think there are four.

Int: Are you sure?

NDP: Yes.

Int: Can you explain?

NDP: Red, X, 1 & blue; Red, Y, 2 & yellow; Green, Z, 3 & blue; and Green, Z, 4 & yellow.

Int: Are there any more paths?

NDP: I think, there are four ways only.

Int: Are you sure?

NDP: Yes.

Int: Thank you.

Task II: Coloured Chemicals (combinatorial reasoning)

Interview with AMP: sex - female, age 13;7.

Interviewer: Here I have got four bottles containing colourless liquids. They are numbered 1, 2, 3, & 4 (pointing at the four bottles). Here I have got another bottle containing a colourless liquid. It is marked 'G'. The liquids in these five bottles are different. Can you repeat what I said.

AMP: There are five different liquids in five bottles.

Int: How do you know they are different?

AMP: They are marked differently (pointing at the bottles).

Int: Here, I have got a test tube containing a colourless liquid. This liquid I have taken from these four bottles. It may be from one of these four bottles or it may be a mixture from two bottles, or from three of them or from all the four put together. Now, I am going to add a few drops of 'G' to it. Let us watch what happens (adds a few drops of liquid G). What happened?

AMP: It turned yellow.

Int: Here, I have got test tubes, I want you to produce the yellow colour by adding liquids from bottles 1, 2, 3, 4 and then adding 'G'. You may do as many experiments as possible.

AMP: But, there are only four tubes,

Int: Dont you worry. I will wash them and give it to you as you proceed.

AMP starts doing the experiments by adding liquids from the bottles to the test tube. Interviewer records the combinations.

AMP: I'm not getting the colour.

Int: Why?

AMP: (no response).

Int: Have you tried all possible ways?

AMP: Yes. (pause) It may be some magic.

Int: Thank you.

Task III: Photosynthesis (controlling of variables)

Interview with RGA (sex - female, age - 13,5)

Interviewer: Have you seen Tulasi and Balsam plants?

RGA: I have seen Tulasi but not Balsam.

Int: Hav'nt you noticed small little plants with pink and white flowers in the school garden i.e., as you enter the school garden on the right hand side there is a row of small flowering plants.

RGA: Yes, They have red, purple and white flowers.

Int: Fine. These plants are called Balsam. I did a few experiments with different parts of these two plants. The details of these experiments are given in these cards. (shows the card given in Appendix B, Task III). I took five glass jars of equal size and filled them with 250 units of carbon dioxide. Do you know what a glass jar is?

RGA: Yes.

Int: In the first jar I kept Tulasi leves, in the second stem of balsam plant, in the third roots of tulasi, in the fourth stem of balsam plant and in the last jar leaves of tulasi. I numbered these jars 1, 2, 3, 4 and 5. I kept the jars under different coloured lights (pointing at the card explains each condition). Also, the temperature at which these jars were kept were different.

Interviewer checks in whether RGA has understood the different conditions by asking probing questions at each point.

Int: All the jars were kept under these conditions for two days. At the end of the second day I measured the amount of CO_2 left in the jars and I found them to be different in different jars. (Explains the quantity of CO_2 in the jars pointing at the table). Now, see whether you can answer this question. If you want to know the amount of carbon dioxide absorbed per day at two different temperatures, which jars would you compare? That is, if you want to know whether at lower temperature or higher temperature the gas is absorbed more which jars would you compare?

RGA: (After a long pause) Jars 1 and 5.

Int: Why?

RGA: Because they are kept at two different temperatures.

Int: Then why not jars 1 and 2. They are also kept at different temperatures.

RGA: They are different plants, also, the conditions are not the same.

Int: Then why not jars 3 and 5 . The plants are the same.

RGA: (After examining the card again). No all the conditions are not same. Only by comparing 1 and 5 you can compare.

Int: Thank you.

Task IV: Pendulum Problem (controlling of variables).

Interview with AKM sex - female, age - 14;0

Interviewer: Here, I have got threads of three different length (pointing at the threads). And, here, I have bobs of different sizes and shapes (pointing at a dish containing the bobs). Here, I have a stand to which you can fix these threads. Using these threads and the bobs I can make different swings (Choolas). Now, I want you to make all possible combinations of choolas and tell which among the choolas take more time to go up and down like this (demonstrates using one of the combinations). I have kept a stop-clock here, if you wish to note the time.

AKM: (removes her wrist watch) She starts doing the experiments. The interviewer makes a detailed note of the procedure adopted by her.

AKM: I think it is the weight.

Int: Why do you think so?

AKM: Heavier the bob, it (the pendulum) moves slower and the lighter one it moves faster.

Int: Has the length anything to do?

AKM: It is all the same.

Int: You want to try again.

AKM: (tries out a few more experiments. In one of the experiments she accidentally hits the heavier bob) The heavier one can also move faster.

Int: Do you wish to try again?

This time AKM approaches the problem by controlling two variables via., the height of the dropping point and mass of the bob.

AKM: I think length of the thread affect the movement.

Int: Can you show it to me?

AKM: (does a few more trials) I think it is the weight.

Int: Are you sure?

AKM: It is the weight and the length which affects.

Int: Thank you.

Task V: Hockey Player Puzzle (combinatorial reasoning)

Interview with KST: sex - male, age - 13;8.

Interwiewer: (after explaining the task as given in Appendix B) How many ways can you wear the gear supplied to you? Try all possible ways.

KST: (after several trials) There are 24 ways.

Int: Can you explain?

KST: Can I write? (interviewer supplies him with a paper and pencil).

Int: What are these?

KST: I'm using letters for colours. (he writes all the 24 ways. using letters for each colour).

Int: Is there any other way?

KST: No, I have written all.

Int: Can you explain them?

KST: With black boots if you change other pieces of the gear, there are twelve ways. So, with white another twelve, making a total of twenty four.

Int: Which are the twelve ways?

KST: I've written them all.

Int: Thank you.

Task VI: Electrical Switching System (Combinatorial reasoning)

Interview with SKK: sex - male, age 13;7

Interviewer: Here, I have got a system of switches connected to a cell. The switches are marked 1, 2, 3, 4 and M.

SKK: (interrupting) Why M? and not 5.

Int: The switch M is called a master switch and so it is named as M. All the switches have two positions i.e., on and off (pointing at the switches). With one of these four switches in the on position; or with any two of them; or with three of them, any three; or with all the four switches in the on position; if you switch on the master switch this bulb would give out light. You try different possible ways to make the bulb glow. Try all possible ways.

SKK: Yes. (puts switch 1 in the on position and then M. Then he switches on 2).

Int: (interrupting) After making one trial put off all the switches before you try again.

SKK: I have to put off 1 and M also?

Int: Yes, switch off all after each trial.

SKK tries in a systematic manner. Interviewer makes a note of all the trials carried out.

SKK: Switches 1 & 3, and M is the combination.

Int: Do you want to try other ways?

SKK: Yes, I would like to.

Int: Try all possible ways (makes a note).

SKK: There are two ways: 1,3 and M; and 1,2,3 and M.

Int: What has switch 2 to do?

SKK: Switches on 1 and 3 and M; then switches on 2 and then puts it off. I think switch 2 has nothing to do.

Int: What about switch 4?

SKK: (tries with all four switches in the on position and then puts off switch 4) I think switch 4 is comimg in the way of the current.

Int: Thank you.

Task VII: Rate of Growth of Plants (Controlling of variables)

Interview with SVC: sex - male, age - 16;3.

Interviewer: Have you seen bean seeds?

SVC: Yes.

Int: Have you noticed any time seeds growing into plants?

SVC: Yes, in my house there is a kitchen garden and I have seen seeds growing into plants.

Int: I did some experiments with bean seeds. I took five mud pots of equal size and numbered them 1, 2, 3, 4 and 5 (pointing at the card). I filled pot 1 with sandy soil, the second also with sandy soil. The third pot I filled with clayey soil. The fourth pot I took a mixture of sandy and clayey soil. The last pot again I filled with sandy soil. I planted five bean seeds each in these pots. I added one mug of water per day to the first pot, three mugs of water to the second and so on as given in this table. I added manure X to pot 1, manure Y to pot 2 and so on. I kept all the pots in these conditions for two weeks. What do you think would happen to these seeds in these two weeks?

SVC: They would grow into plants.

Int: I measured the length of the plants in all these five pots. In the first pot they have grown to 14 cms., in the second to ten cms., and so on as given. Now, try to answer this question: If you want to know the length to which the plants have grown, per week, under two light conditions viz., sun and shade, which two pots would you compare?

SVC: After a long pause. Pots 2 and 5.

Int: Why have you chosen 2 and 5? Can you give me a reason?

SVC: Both are kept in sun.

Int: If you want to compare the difference in growth of plants kept in sun and shade which pots would you compare?

SVC: 1 and 2.

Int: Why?

SVC: They are kept in sun and shade and water added is more in one and less in the other.

Int: If water added is more the plants in pot 2 should grow taller. But, they are shorter.

SVC: May be there is some other reason. I dont know.

Int: Thank you.

Task VIII: Falling Bodies on an Inclined Plane (controlling of variables)

Interview with SIP: sex - female, age - 13;11.

The interviewer describes the apparatus as given in Appendix B with intermittent questions to ensure the understanding of SIP.

Interviewer: Now, I want you to tell me, after doing experiments, what makes the bob go further; whether it is the height of the plane, distance from the bottom curve of the plane, the mass of the bob or the size of the bob?

SIP: (after making several observations with different bobs in an unsystematic manner). The balls will go in holes, further away, in order of size (pointing at the apparatus).

Int: What do you mean by order of size? Can you explain?

SIP: The smallest goes to the nearest hole and the biggest goes to the farthest. Those in the middle goes to the middle (she demonstrates it).

Int: So, they go according to size. Has the height of the plane anything to do?

SIP: According to where you put the slide (pointing at the inclined plane) they go in the holes. You put it up the ball falls nearer. It depends on the slide also.

Int: Are you sure?

SIP: I think the size has nothing to do. The weight and the plane affect it.

Int: Do you wish to try again?

SIP: No. I have already completed all the experiments.

Int: Thank you.

APPENDIX F

Pre Assessment of Group 1 [O_1]
(IX A 1981-'82)

Sr. No.	Name*	Sex	Age●	Combinatorial reasoning		Controlling of variables	
				Task I	Task II	Task III	Task IV
1	AMP	F	13;7	II B	II B	II A	II A
2	KLP	F	12;10	II A	II B	II A	II A
3	ASL	F	13;9	II A	II A	II A	II A
4	PKY	F	13;11	II B	II B	II B	II B
5	RHS	M	14;10	II A	II A	II A	II A
6	NDP	M	13;11	II A	II B	II B	II B
7	SKK	M	13;7	II A	II B	II A	II B
8	SKD	M	14;7	II B	II B	II A	II B
9	KBI	M	13;10	II B	II B	II B	II B
10	KHJ	M	14;2	III A	II B	II A	II A
11	KST	M	13;8	III A	III A	III A	III A
12	JRA	M	15;4	II A	II A	II A	II A
13	DES	M	15;6	II A	II A	II A	II A
14	UYA	M	14;0	II A	II A	II A	II B
15	DMH	M	13;8	II A	II B	II A	II A
16	JAS	M	14;0	II B	II B	II B	II B
17	ADG	M	13;10	II A	II A	II A	II A
18	RMD	M	12;9	II B	II B	II B	II B
19	MMG	M	14;9	II B	II B	II A	II A
20	BHP	M	14;6	II A	II A	II A	II A
21	ASP	M	13;6	II A	II A	II A	II A
22	GID	M	13;4	II A	II B	II A	II A
23	MJB	M	14;11	II B	II A	II B	II A
24	NLG	M	15;0	II B	II B	II A	II A
25	RPG	M	14;9	II A	II A	II A	II A
26	NGM	M	14;8	II A	II A	II A	II A

* short forms of the names are used

● Age as on the assessment day, year;months.

F - female

M - male

Sl. No.	Name	Sex	Age	Combinatorial reasoning		Controlling of variables	
				Task I	Task II	Task III	Task IV
27	RAC	M	14;7	II A	II A	II A	II A
28	TMS	F	14;8	II A	II A	II A	II A
29	SAS	M	15;0	II A	II A	II A	II A
30	UMI	M	15;7	II A	II A	II A	II A
31	LKP	M	14;5	II A.	II A	II A	II A
32	AHK	M	16;7	II A	II A	II A	II A
33	VSI	M	14;5	II A	II A	II A	II A
34	RAM	F	14;10	II A	II A	II A	II A
35	PKP	F	15;3	II A	II A	II A	II A
36	AKP	M	14;4	II A	II A	II A	II A
37	SPA	F	13;9	II B	II B	II A	II A
38	RGA	F	13;5	III A	III B	II B	II B
39	KPK	F	14;5	II B	II A	III A	II B
40	AKP	F	13;6	II A	II A	II A	II A
41	PBT	F	13;5	II A	II B	II A	II A
42	MMD	M	14;10	II B	III A	II A	II A
43	AFK	M	15;5	II A	II B	III A	II B
44	STT	M	14;2	II A	II A	II A	II A
45	PLS	F	13;7	II A	II A	II A	II A
46	SYG	F	14;0	II B	II A	II A	II A
47	JKT	M	14;11	II A	II A	II A	II A
48	NSI	M	14;3	II A	II A	II A	II A
49	HPL	M	14;0	II A	II A	II A	II A
50	RMI	M	16;2	II A	II A	II A	II A

Pre Assessment of Group 2 [O_3]
(IX A 1982-'83)

Sr. No.	Name*	Sex	Age@	Combinatorial reasoning		Controlling of variables	
				Task I	Task II	Task III	Task IV
1	SVC	M	15;10	II A	II A	II A	II A
2	IVT	M	15;5	II A	II A	II A	II A
3	KJS	M	15;11	II A	II A	II A	II A
4	PLP	F	16;4	II A	II A	II A	II A
5	PLB	M	15;6	II A	II A	II A	II A
6	AAS	F	16;6	II A	II A	II A	II A
7	MAD	F	13;6	II B	II B	II A	II A
8	HMI	F	14;8	II A	II A	II A	II A
9	JMI	F	15;2	II A	II A	II A	II A
10	PYS	F	16;3	II A	II A	II A	II A
11	BIP	F	14;8	II A	II A	II A	II A
12	DAP	F	13;9	II A	II A	II A	II A
13	DIP	F	14;0	II B	II B	II B	II B
14	PGP	F	15;0	II A	II A	II A	II A
15	SIS	F	15;1	II A	II A	II A	II A
16	RMV	F	14;2	II A	II A	II A	II A
17	KPS	M	14;10	II B	II B	II B	II B
18	RNA	M	14;11	II A	II A	II A	II A
19	SCB	M	14;9	II A	II B	II A	II B
20	DLB	M	13;7	II A	II B	II B	II B
21	MHD	M	13;4	II A	II A	II A	II A
22	NJD	M	13;5	II A	II B	II A	II B
23	DJL	M	14;3	III A	III A	III A	III A
24	RJJ	M	13;6	II A	II A	II A	II A
25	NHK	M	13;9	II A	II B	II B	II A
26	GLA	M	15;2	II B	II B	II B	II B

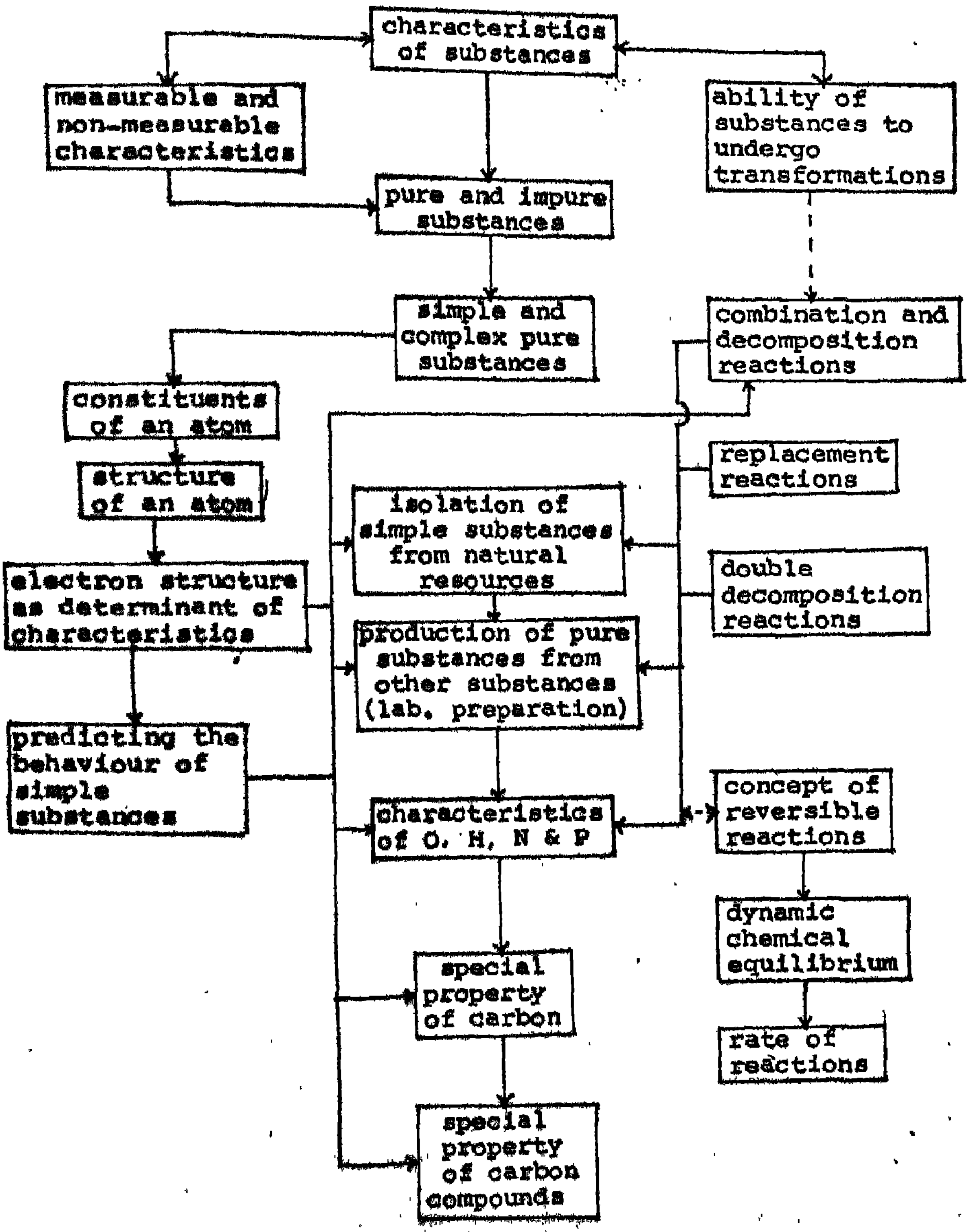
*Short forms of the names are used. F - female

@Age as on assessment day in years ; months. M - male

Sl. No.	Name	Sex	Age	Combinatorial reasoning		Controlling of variables	
				Task I	Task II	Task III	Task IV
27	KGM	M	13,3	II B	II B	II B	II B
28	HNR	M	13,0	II A	II A	II A	II A
29	GPA	M	15,5	II A	II A	II A	II A
30	RJP	M	14,3	II B	II B	II B	II B
31	NMP	M	14,6	II A	II A	II A	II A
32	PSP	M	15,2	II A	II A	II A	II A
33	MSY	M	13,4	II B	II B	II B	II B
34	STS	M	14,3	II A	II A	II A	II A
35	SJS	M	14,5	II A	II A	II A	II A
36	VYS	M	14,7	II A	II A	II A	II B
37	MLS	M	15,6	II A	II A	II A	II A
38	BKS	M	14,4	II A	II A	II A	II A
39	PBI	M	14,0	II B	III A	II A	II A
40	NAB	F	14,3	II A	II A	II A	II A
41	SYG	M	14,9	II A	II A	II A	II A
42	LCD	M	14,5	II B	II B	II A	II B
43	KNJ	M	14,8	II A	II A	II A	II A
44	MJK	M	14,6	II A	II A	II A	II A
45	NHK	M	13,3	II B	II B	II B	II B
46	KPT	M	13,5	II A	II A	II A	II A
47	HYP.	M	14,5	II A	II A	II A	II A
48	SYP	M	15,5	II B	II B	II B	II A
49	DHR	M	15,4	II A	II A	II A	II A
50	SUS	M	15,1	II B	II B	II A	II B
51	NHS	M	13,9	II B	II B	II A	II B
52	RJS	M	13,9	II A	II A	II A	II A

APPENDIX G

Re-structured Chemistry Content of Grade IX



APPENDIX H

Sample Classroom Interactions of the Treatment

Sample 1: Combination of Elements to form Compounds Based on Electron Structure.

Teacher: last few sessions we discussed about the electron structure of atoms. Give me two examples of elements having one electron in the outer orbit.

Student: Hydrogen.

T: How many electrons does it have?

S: One.

T: What is the arrangement?

S: One in the first orbit,

T: Give me another example.

S: Sodium.

T: What is it's atomic number?

S: Eleven.

T: Then, what is the electron structure?

S: 2, 8, 1.

T: (writes both the structures on the blackboard) give me an example of an element with two electrons in the outer orbit.

S: Magnesium with 2, 8, 2. (T writes on the blackboard)

T: With three electrons.

S: Aluminium with 2, 8, 3. (T writes on the b.b.)

T: With four?

S: Carbon with 2, 4. (T writes on the b.b.)

T: Examples with five, six, seven and eight electrons?

S: Nitrogen with 2, 5; Oxygen with 2, 6; Chlorine with 2, 7 and Neon with 2, 8. (T writes all on the b.b.)

T: Does Neon form compounds?

S: NO, because it has a stable electron structure of eight.

T: What about the rest of elements with less number of electrons in the outer orbit?

S: All those elements form compounds.

T: Why?

S: Because they have less than eight electrons in the outer orbit.

T: Now, here, I have written the electron structures of Na, Mg,

Al, C, N, O and Cl. They all have unstable electron structure in their outer orbits. Are these structures stable or not?

S: They are all unstable.

T: How can they attain stability? Suggest any one way in which two elements can attain stability.

S: Na can loose one electron and Cl can take that.

T: When sodium looses one electron what happens to its electron structure?

S: It becomes 2, 8; like that of Ne.

S: Ne has a stable structure.

T: What charge would Na acquire?

S: ....

T: How many electrons are there in a sodium atom?

S: eleven negative.

T: So, if we remove one electron what would happen to the atom?

S: There would be ten negative.

T: How many positive particles are there in the Sodium atom.

S: Eleven positive.

S: So, the Sodium atom which has lost one electron will acquire one positive charge.

T: How can we represent it?

S: With a negative sign.

T: Sodium with all electrons is called an atom and when it acquires a positive charge it is called an 'ion'. What would happen to Cl atom when it acquires one more electron?

S: It would get eighteen electrons.

S: It will have an extra negative charge.

T: Will it remain an atom?

S: No, it will become a negative 'ion'.

T: How many negative charges will it acquire?

S: One.

T: Why?

S: Because it has acquired only one electron.

T: The positive and negative particle stays together because of their attraction. Thus the compound NaCl is formed.

S: What happens to the charges when they form a compound?

S: The positive of Na and negative of Cl becomes equal.

T: The charges get neutralised. If one of the ions had two positive charges, will it be neutralised by one negative.

S: Yes, because they are positive and negative they will get neutralised.

S: No, only one will get neutralised. It will have one positive.

T: Let us take an example for discussion. How many electrons have magnesium in the outer orbit?

S: Two.

T: How can it attain stability?

S: By loosing the two outer electrons.

T: Suppose it looses its electrons to Chlorine. Then, how can it attain stability?

S: Chlorine can take only one. So Mg cannot give both of them.

S: Cl will take both because it takes electrons.

S: Then Cl will not be stable.

T: Why woud'nt it be stable?

S: Because it will have nine electrons. This is not stable. Eight is stable.

T: Then how can Mg attain stability?

S: It may loose the electrons to any other element.

T: Can you suggest?

S: Oxygen has six in the outer. It needs two more. Mg can give both its electrons to oxygen.

S: Mg can lose its electrons to two Cl atoms.

S: How is it possible?

S: We know that Magnesium chloride is there like Sodium Chloride. Mg looses one electron each to two Cl atoms.

T: Then how will we represent acompound of Mg and Cl.

S: Mg Cl Cl.

T: Instead of Mg Cl Cl, it is usually represented as $MgCl_2$.

T: Will Mg and O form a compound?

S: Mg can give both its outer electrons to one O forming MgO.

T: What will be the charge of the Mg ion.

S: It will have two positive charges and O will acquire two negative charges.

T: How will Al with three electrons in the outer orbit attain stability?

S: It can give one each to three Cl atoms.

T: What would be the charge acquired by Al?

S: It will acquire three positive charges.

S: How can it attain three positive charges?

S: It will give three electrons to one Cl atom each. Because it has given out three negative charges it would get three positive.

T: Will Al and O form a compound and if so how? You try to find an answer. We will discuss it during the next session. Now let us take two other examples, say, Na and Mg. Will they combine to form compounds?

S: Yes, Na will loose one electron and Mg will loose two.

S: It is not possible. Mg will have only three and that is not stable.

S: Na and Mg would loose electrons. Then they are stable.

S: Both would be positive and they will not attract.

S: Positive and positive repels.

T: Yes, like charges repel.

S: Then six Na can loose one electron each to one Mg.

S: Then what would be the charge of Mg?

S: Six negative.

T: So far I have'nt heard of such a compound. But, it may be possible. As you learn further you'll learn about it.

Sample 2: Factors Affecting Rate of a Reaction

T: Here I have two solid substances. Are they the same?

S: No.

T: Why do you say so?

S: Their colour is different.

S: Their shape is different.

S: One is a grey solid and the other is reddish brown pieces.

T: To these two substances I'm adding two colourless liquids. (adds Con. H_2SO_4 to Cu turnings and dil. HCl to Zn rod) What is happening in these two test tubes?

S: A reaction is taking place.

T: How do you know?

S: New substance is produced.

S: In the first a reddish brown gas is produced.

S: It has a suffocating smell.

S: In the second a colourless gas is produced.

T: In this test tube a reaction is taking place where a reddish brown gas is produced and in this test tube a colourless gas is produced. What are the differences in these two reactions?

S: The colour of the gas produced is different.

S: The substances taken are different.

S: This gas has a bad smell, the other one does not have.

S: Here the reaction is faster and here it is slow.

S: No, if you add more acid to this it will also go on faster.

T: Let us try. (adds a few more drops of the acid to the Zn rod.

S: Then also it is slow.

S: May be it needs more acid.

T: Let us try again (adds more acid to the same test tube).

S: There is no difference. This must be a slow reaction.

T: Yes some reactions are slower than others. Here this one is slower than the other. There are other examples. Rusting of Iron where Iron changes into a reddish powder. Is that a slow or fast reaction?

S: It is a slow reaction, because it takes a long time for Iron to become rust.

T: How do you call a reaction as a slow reaction?

S: If the new substance is produced at a fast rate it is a fast reaction. If it goes on slowly it is a slow reaction.

T: What could be the possible reasons for these two reactions to be of different rate?

S: The acid added is different.

T: I'll repeat the experiment with the same amount of acid.

S: No the weight of the substance has also to be the same.

S: Only if the weight is the same we can know the difference.

T: (weighs out equal amount of Cu and Zn and adds the same quantity of acid to both). Here the acids are different. One is H_2SO_4 and the other is HCl. What do you observe?

S: One reaction is fast and the other is slow.

S: The difference is because the substance used is different.

S: All others are equal. So the difference is because of the substance.

T: One factor that determines the rate of a reaction is the nature of the substance.

T: Here I have Zn in three different forms. One, is a rod. The second is in the form of small pieces and the third is in the form of a powder. If I add the same amount of acid to all the three forms will the reaction rate be the same?

S: The matetial is the same and so the rate would be the same.

S: The weight of the three forms should be equal.

S: No, it is not required because the material is the same.

T: Why do you say that the weight has to be the same? (pointing at he student who gave such a hypothesis).

S: If the weights are different we cannot know whether the speed of the reaction changes because of the form of the material.

T: Let us perform the experiment. What have we got to take?

S: Equal weights of the three forms.

Teacher weighs equal quantity of the three forms of Zinc.

S: We have to add equal quantity of acid.

Teacher measures out equal quantity of the acid and adds to the three test tubes.

T: What do you observe?

S: The Zn powder reacts faster and the rod reacts very slowly.

T: What does this indicate?

S: The rate of the reaction depend on the condition of the substance whether it is a rod or a piece or powder.

T: Another factor which determines the rate of a reaction is the physical nature of the substance. The rod has less area for the acid to come in contact and so the reaction is slow.

S: The pieces will have more area where the acid can come and react and so the reaction goes on faster.

S: The powder has the maximum area where the acid can come and react. Therefore, the reaction goes on very fast.

T: The surface area increases as we make the big piece into smaller ones and the acid finds more place for reaction.

T: Suppose the two substances are in the form of gases, will they react faster or slower?

S: They will react fast?

S: Why?

S: Because the substances come in contact with a larger area.

T: How do you say this?

S: Because in gases the molecules are free to move around and the molecules of the two substances will come in contact and hit each other for the reaction, to take place.

T: If such a reaction is very very fast, how long will it take to complete the reaction?

S: Only a few seconds.

S: May be even less.

T: Yes, certain reaction are so fast that the reaction is complete within fractions of seconds. Can you suggest any such example?

S: ....

T: If we mix H and Cl in presence of light the mixture will react so violently that it explodes.

S: Can we do the experiment in the class?

T: Sorry, it is very dangerous.

S: The test tube will break and teacher will get hurt.

T: Such reactions are not carried out in test tubes and so we cannot perform in the classroom.

S: The noise would disurb other classes also.

T: If we want to measure the rate of a reaction how can we do it? How do we express the speed of a moving car?

S: km per hour.

T: Similarly how can we express the rate of a reaction?

S: Amount of substance produced per hour.

T: If the reaction is a faster one and it goes to completion within a few minutes, then how would you express it?

S: Amount of substance produced per minute.

T: Depending on the reaction the unit may be changed but in all these cases the amount produced per unit time is taken as the rate of reaction.

S: If it is a very fast reaction then it may be expressed as the substance produced per second.

T: How will you express the rate of rusting of Iron?

S: Amount of rust produced per day.

The teacher goes on to revise the factors that affect the rate of reaction one by one and writes them on the black board.

APPENDIX I

Sample Lessons of the Control Groups

Sample 1: Occurance and allotropic forms of Phosphorous

Teacher: Today we'll learn Phosphorous. Anyone who can tell me the symbol of phosphorouus.

S: P

T: Good. The symbol of Phosphorous is P. The atomic number is 15 and the atomic weight is 31. Phosphorous is a very reactive element and so it is not found free in nature. It is found in the compound form. The chief minerals of phosphorous are Phosphorite, Fluoropatite and Chloropatite (teacher writes the formula of the minerals on the board). Phosphorous is present in the compound form in the body of animals and plants. Your bones are made of phosphorous compounds. P is obtained by heating the minerals with coke and sand in an electric furnace.
P shows allotropy. What is allotropy?

S: Existing in different forms.

T: An element which shows different physical forms but the same chemical composition is called allotropy. P exihibts mainly three allotropic forms 1) white or yellow phosphorous, 2) red phosphorous and 3) black phosphorous. Ordinary P is white in colour and it turns yellow when exposed to light. It is a soft solid and can be cut easily with a knife. It catches fire if exposed to air. This is because it is highly reactive. P is reactive because of its special structure. (Teacher draws the structure on the board and continues with the explanation).

T: What is the molecular formula of P?

S: P_4.

T: What is the atomic number?

S: 15.

T: What is the atomic weight?

S: 31.

T: What are the allotropic forms?

S: Yellow, red and black phosphorous.

T: Write down this question and answer. How does P occur in nature? Give its important minerals.

Teacher dictates the answer.

Sample 2: Exothermic and Endothermic Reactions

T: What do we do when we want heat?

S: We burn wood, coal.

S: Switch on a heater.

S: Burn kerosene.

S: We burn things.

T: Burning of coal, kerosene etc., are chemical changes. When coal burns carbon dioxide and heat are produced. When wood is burned the carbon present in the wood combines with oxygen to form carbon dioxide. The hydrogen present in the wood combines with the oxygen in the air producing water. There are many other chemical reactions where heat is produced when the reaction occurs. Such reactions are called Exothermic reactions. Other examples of exothermic reactions are: 1) carbondioxide is produced when carbon monoxide is burned in oxygen i.e., $CO + O \rightarrow CO_2 + 67.6$ K cal. (teacher writes the equation on the blackboard). A lot of heat is produced in this reaction and so it is called an exothermic reaction. 2) when hydrogen burns in oxygen a lot of heat is produced, about 57.8 kilo calories of heat. The equation for the reaction is $H_2 + O \rightarrow H_2O + 57.8$ K. Cal. Exo means giving out and thermic is connected to heat. Therefore, exothermic reactions are where heat is given out during the reaction.

The teacher then goes on to explain endothermic reactions.

T: Take down this question and answer. Define exothermic reaction and give two examples.

Teacher dictates the notes to the students.

APPENDIX J

Assessment of reasoning patterns of Group 1 $[O_2]$

Sr. No.	Name*	Sex	Age#	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
1	AMP	F	14;0	III A	III A	II B	II B
2	KLP	F	13;3	III A	III A	II A	II A
3	ASL	F	14;2	III A	III A	II B	II B
4	PKY	F	14;5	III A	III A	II B	II B
5	RHS	M	15;4	II A	II A	II A	II A
6	NDP	M	14;4	II B	III A	II B	III A
7	SKK	M	14;0	II B	III B	II B	III A
8	SKC	M	15;0	III B	III A	II B	II B
9	KSI	M	14;3	III A	III B	III A	II B
10	KHJ	M	14;7	III A	II B	II A	II A
11	KST	M	14;1	III B	III B	III A	III A
12	JRA	M	15;9	II A	II B	II A	II A
13	DES	M	15;11	II A	II A	II A	II A
14	UYA	M	14;5	II A	II B	II A	II B
15	DMH	M	13;7	II B	III A	II B	II B
16	JAS	M	14;6	III A	III A	II B	III A
17	ADG	M	14;3	III A	III A	II B	II A
18	RHD	M	13;4	III A	III A	II B	II B
19	MKG	M	15;4	III A	III A	III A	III A
20	BHP	M	14;11	II A	II A	II A	II A
21	ASP	M	13;11	II A	II B	II A	II A
22	GID	M	13;9	III A	III A	III A	II B
23	MJS	M	15;4	II B	II A	II B	II A
24	NLG	M	15;5	III A	III A	II A	II A
25	RTG	M	14;5	II B	II B	II A	II A

* short forms are used.

\# age as on assessment day in years;months.

F - female

M - male

Sr. No.	Name	Sex	Age	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
26	NGM	M	15;1	II B	II B	II B	II B
27	RAC	M	15;0	II A	II A	II A	II A
28	TMS	F	15;1	II B	II B	II A	II A
29	SAS	M	15;5	II A	II A	II A	II A
30	VMI	M	16;0	II B	II B	II A	II A
31	LKP	M	14;10	II A	II A	II A	II A
32	AHK	M	16;11	II A	II A	II A	II A
33	VSI	M	14;10	II A	II A	II A	II A
34	RAM	F	15;3	III A	III A	II A	II A
35	PKP	F	15;8	II A	II A	II A	II A
36	AKP	M	14;9	II A	II A	II A	II A
37	SPA	F	13;2	II B	II B	II A	II A
38	RGA	F	13;10	III B	III B	III A	III B
39	KPK	F	14;10	III A	III A	II B	II B
40	AKP	F	13;11	II A	II A	II A	II A
41	PBT	F	13;10	II B	II B	II A	II A
42	MMD	M	14;3	III A	III A	II A	II A
43	AFK	M	15;10	II B	II B	III B	III A
44	STT	M	14;7	II A	II A	II A	II A
45	PLS	F	14;0	II A	II A	II A	II A
46	SYG	F	14;5	III A	III A	III A	III A
47	JKE	M	14;11	II A	II A	II A	II A
48	NSI	M	14;8	III A	III B	III A	III B
49	HPL	M	14;5	II A	II A	II A	II A
50	RMI	M	16;7	II A	II A	II A	II A

Assessment of Reasoning Patterns of Group 2 [n4]

Sr. No.	Name*	Sex	Age#	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
1	SVC	M	16;3	II A	II A	II A	II A
2	IVP	M	15;10	II A	II A	II A	II A
3	KJS	M	16;4	II A	II A	II A	II A
4	PLF	F	16;9	II A	II A	II A	II A
5	PLB	M	15;11	II A	II A	II A	II A
6	AAS	F	16;11	II A	II A	II A	II A
7	MAD	F	13;11	III A	III A	II B	II B
8	HHI	F	15;1	II A	II A	II A	II A
9	JMI	F	15;7	II B	II B	II A	II A
10	FYS	F	16;8	II A	II A	II A	II A
11	BIP	F	15;1	II A	II B	II A	II A
12	DAP	F	14;2	II B	II B	II B	II B
13	DIP	F	14;5	III A	III A	II B	II B
14	PGP	F	15;5	II A	II A	II A	II A
15	SIS	F	15;6	II B	II B	II A	II A
16	RMV	F	14;7	II A	II A	II A	II A
17	KFS	M	15;3	III A	III A	III A	III A
18	RNA	M	15;4	II A	II B	II A	II A
19	SCB	M	15;2	II B	II B	II A	II B
20	DLB	M	14;0	II A	II B	II B	II B
21	MHD	M	13;9	II A	II A	II A	II A
22	NJD	M	13;10	II B	II B	II B	II B
23	DJL	M	14;8	III B	III B	III A	III A
24	RJJ	M	13;11	II B	II B	II A	II A
25	NHK	M	14;2	II A	II B	II A	II A
26	GLA	M	15;6	III A	III A	III A	III A

* short forms are used

\# age as on assessment day in [illegible]

F - female

M - male

Sr. No.	Name	Sex	Age	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
27	KGM	M	13;8	II B	II B	II B	II B
28	HNR	M	13;5	II B	II B	II B	II B
29	GDA	M	15;10	II A	II A	II A	II A
30	RJP	M	14;8	III A	III A	III A	III A
31	NMP	M	14;11	II A	II A	II A	II A
32	PSF	M	15;7	II A	II A	II A	II A
33	MSY	M	13;9	II B	II B	II B	II B
34	STS	M	14;8	II A	II A	II A	II A
35	SJS	M	14;10	II A	II A	II A	II A
36	UYS	M	14;11	II A	II B	II B	II B
37	MLS	M	15;11	II A	II A	II A	II A
38	BKS	M	14;9	II A	II A	II A	II A
39	PBI	M	14;5	II B	III A	II A	II A
40	NAB	F	14;3	II B	II B	II A	II A
41	SYG	M	15;2	II A	II A	II A	II A
42	LCD	M	14;10	II B	II B	II B	II B
43	KNJ	M	15;0	II A	II A	II A	II A
44	MJK	M	14;11	II A	II A	II A	II A
45	NHK	M	13;8	II B	II B	II B	II B
46	KPT	M	13;10	II A	II A	II A	II A
47	HYP	M	14;10	II A	II A	II A	II A
48	SYP	M	15;10	II B	II B	II B	II A
49	DHR	M	15;9	II A	II A	II A	II A
50	SUS	M	15;6	II B	II B	II B	II B
51	NHS	M	14;2	II B	II B	II A	II B
52	RJS	M	14;2	II A	II A	II A	II A

Assessment of Reasoning Patterns of Group 3 $\left[0_5\right]$

Sr. No.	Name*	Sex	Age#	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
1	PBT	F	15;6	II A	II A	II A	II A
2	CTM	F	13;11	II B	II A	II A	II A
3	ADS	F	15;6	II A	II A	II A	II A
4	DAD	F	14;4	III A	III A	III A	II B
5	RDI	F	14;4	II B	II B	II A	II A
6	UAG	F	15;2	II A	II A	II A	II A
7	[illegible]	F	15;9	II A	II A	II A	II A
8	[illegible]K	F	14;5	II A	II A	II A	II A
9	BHM	F	15;1	II A	II A	II A	II A
10	PMR	F	14;5	II A	II A	II A	II A
11	BMD	F	13;11	III A	III A	II A	II A
12	KAM	F	14;4	III A	III A	II B	II B
13	A[illegible]M	F	14;0	III A	III A	III A	III A
14	RKM	F	16;4	II B	II A	II A	II A
15	SAM	F	15;0	II A	II A	II A	II A
16	KLP	F	14;4	III A	III A	II A	II A
17	NKP	F	14;0	II B	II A	II A	II A
18	STP	F	13;11	III A	III A	III B	III A
19	VAP	F	15;1	II A	II A	II A	II A
20	NZP	F	15;7	III A	III A	II B	II B
21	[illegible]O	F	14;5	III B	III A	II B	II B
22	JSI	F	14;4	III A	III A	III A	II B
23	RIS	F	14;2	II A	II B	II A	II B
24	PLJ	F	15;1	II A	II B	II A	II A
25	SOT	F	15;2	III A	III A	II B	II B
26	GJV	F	[illegible];5	III A	III A	II B	II A

* [illegible] forms are used

F – female

\# [illegible] assessment day in years;months

Sr. No.	Name	Sex	Age	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
27	AAG	M	14;9	III A	III A	III B	III B
28	VDS	M	15;7	III A	III B	II A	II B
29	JLJ	M	14;4	III A	III A	III A	II B
30	PTD	M	13;8	II A	II A	II A	II A
31	SDE	M	14;5	III A	III A	II B	II B
32	PVE	M	15;7	II A	II A	II A	II A
33	MJA	M	13;9	III B	III B	II B	II B
34	SYJ	M	14;2	II A	II A	II A	II A
35	KBJ	M	13;11	III A	III A	II A	II A
36	SLI	M	13;10	III A	III A	III A	III A
37	MMA	M	15;11	II A	II A	II A	II A
38	AMM	M	16;6	III A	III B	III B	III A
39	ART	M	14;4	III B	III A	II B	II B
40	DHP	M	13;6	II A	II A	II A	II A
41	JHP	M	13;11	II A	II A	II A	II A
42	KKP	M	14;4	II A	II B	II A	II A
43	MHP	M	13;11	III A	III B	III A	III B
44	MGP	M	14;2	III A	III A	II A	II A
45	UKP	M	15;9	III A	III A	III A	III A
46	AJP	M	13;7	II A	II B	II A	II A
47	RDI	M	15;1	II B	II B	II A	II A
48	HLS	M	14;8	II A	II A	II A	II A
49	JHS	M	13;9	III A	II B	II A	II B
50	JIM	M	14;6	II A	II A	II A	II A
51	RAV	M	15;5	III A	III A	II B	II B
52	ALS	M	15;10	III A	III A	II B	III A

M- male

Assessment of Reasoning Patterns of Group 4 [P_6]

Sr. No.	Name*	Sex	Age#	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
1	VAW	F	15;5	II A	II A	II A	II A
2	BLN	F	15;9	II A	II A	II A	II A
3	IAD	F	16;3	II B	II A	II A	II A
4	NAD	F	14;11	II B	II A	II A	II A
5	[illegible]LI	F	15;10	II A	II A	II A	II A
6	SDX	F	14;8	II B	II B	II A	II A
7	A[illegible]D	F	15;1	II A	II A	II A	II A
8	MAH	F	15;5	II A	II A	II A	II A
9	AKM	F	14;2	II A	II A	II A	II A
10	STK	F	13;10	III A	III A	II B	II B
11	BKL	F	15;7	II A	II A	II A	II A
12	KAM	F	15;0	II A	II A	II A	II A
13	DIN	F	14;0	II B	II B	II A	II A
14	VIN	F	14;6	II A	II A	II A	II A
15	NAS	F	13;6	II A	II A	II A	II A
16	DTS	F	15;10	II B	II B	II B	II B
17	RMP	F	14;0	II A	II A	II A	II A
18	IAP	F	16;2	II A	II A	II A	II A
19	VAP	F	13;7	II A	II A	II A	II A
20	PNT	F	14;1	II A	II A	II A	II A
21	VAI	M	15;10	II A	II A	II A	II A
22	LBI	M	16;2	II A	II A	II A	II A
23	HPC	M	14;4	II B	II B	II B	II B
24	MS[illegible]	M	15;4	II A	II B	II A	II A
25	JNP	M	15;5	II B	II A	II A	II A

* short forms are used

\# age as on assessment day in years;months

F – female

M – male

Sr. No.	Name	Sex	Age	Combinatorial reasoning		Controlling of variables	
				Task V	Task VI	Task VII	Task VIII
26	TLG	M	13;5	II B	II B	II B	II B
27	NHG	M	13;8	II B	II B	II A	II A
28	NHK	M	15;1	II A	II A	II A	II A
29	BTK	M	15;11	II A	II A	II A	II A
30	SYK	M	14;11	II B	II B	II B	II B
31	KBK	M	16;1	II A	II A	II A	II A
32	MLT	M	14;5	II B	II B	II B	II B
33	NLP	M	14;4	II B	II B	II B	II B
34	RPY	M	15;7	II A	II A	II A	II A
35	BTP	M	14;6	II B	II B	II B	II B
36	DPP	M	15;8	II A	II A	II A	II A
37	JTK	M	13;7	III A	III A	III A	III A
38	RVP	M	14;9	II A	II A	II A	II A
39	RHP	M	13;11	II A	II A	II A	II A
40	RKP	M	14;6	II B	II B	II B	II B
41	SRP	M	14;4	III A	III A	II B	III A
42	HRO	M	14;0	II A	II A	II A	II A
43	AGS	M	14;11	II B	II B	II B	II B
44	DGH	M	13;10	II A	II A	II A	II A
45	VPS	M	15;1	II B	II B	II A	II A
46	HLS	M	13;5	II B	II B	II A	II A
47	VTS	M	15;11	II A	II A	II A	II A
48	JDM	M	13;10	II A	II A	II A	II A
49	RKJ	M	14;5	II B	II B	II B	II B
50	KLP	M	15;6	II A	II A	II A	II A

APPENDIX K

Recordings of Classroom Interaction using BOCOPBI

Sample 1: Topic - Placement of electrons in an atom

Teacher - PAK Observer - SBM

Date: 27-11-1981 Class - IX A

[T_{11}, T_{61}, T_{11}, T_{22}, S_{11}, T_{23}, S_{41}, T_{23}, S_{11}] wave nature of energy. [T_{11}, T_{61}, T_{22}, S_{27}, T_{14}, S_{27}, S_{17}, T_{16}, T_{23}, S_{17}, T_{16} T_{23}, S_{17}, S_{16}, T_{27}, S_{11}, T_{16}, T_{27}, S_{15}, S_{16}, T_{32}, S_{17}, S_{18}, T_{32} S_{11}, T_{11}, T_{22}, S_{11}, T_{32}, S_{11}, T_{14}, T_{23}, S_{14}, S_{27}, T_{32}, S_{14}, T_{27} S_{14}, T_{31}, S_{14}, T_{32}, S_{15}, S_{15}, S_{15}, T_{32}, S_{16}, S_{17}, T_{22}, S_{18}, S_{18} T_{32}, S_{19}/T_{19}] electrons are at different energy levels in an atom.

Sample 2: Topic - Transformation of substances

Teacher - PAK Observer - SBM

Date: 8-12-1981 Class - IX B

[T_{11}, T_{21}, S_{11}, T_{61}, T_{22}, S_{11}, T_{62}, S_{11}, T_{21}, S_{11}] recalling and performing several changes that occur to substances.

[T_{11}, T_{61}, T_{62}, S_{14}, T_{23}, S_{14}, S_{15}, T_{31}, S_{15}, T_{16}, S_{11}, T_{41}, T_{23}, S_{14}, T_{23}, S_{15}, T_{27}, S_{15}] melting of wax. [T_{11}, T_{22}, S_{11}, T_{23}, S_{14}, T_{32}, S_{14}, T_{42}, S_{15}, T_{72}, S_{15}, T_{23}, S_{14}, T_{42}, S_{15}] burning of candle. [T_{11}, T_{61}, T_{62}, S_{61}, T_{23}, S_{64}, S_{64}, T_{42}, S_{65}, S_{65}] burning of Magnesium. [T_{11}, T_{61}, T_{63}, T_{62}, S_{64}, T_{42}, S_{65}, S_{27}, T_{27}, S_{27}] precipitation of Silver chloride. [T_{11}, T_{21}, T_{23}, S_{14}, T_{42}, S_{15}, T_{43}, S_{14}, S_{14}, S_{18}, T_{18}, T_{23}, S_{18}, S_{18}] classification of changes.

Sample 3: Topic - Combination of elements based on electron structure.

Teacher - PAK Observer - SBM

Date: 17-12-1981 Class - IX A

$[T_{11}, T_{22}, S_{11}, T_{22}, S_{11}, T_{22}, S_{11}, T_{62}, T_{23}, S_{14}, T_{22}, S_{11}, T_{23}, S_{14}, T_{27}, S_{14}, S_{15}, T_{16}, T_{23}, S_{14}, T_{32}, S_{15}, S_{11}, T_{32}, S_{16}, T_{27}, S_{11}, T_{23}, S_{14}, S_{16}, T_{11}]$ compound formation of NaCl. $[T_{11}, T_{23}, S_{14}, T_{27}, S_{14}, S_{15}, S_{11}, T_{22}, S_{14}, S_{15}, T_{32}, S_{16}, T_{32}, S_{11}]$ Magnesium compounds. $[T_{11}, T_{23}, S_{14}, S_{15}, T_{32}, S_{15}, T_{11}, S_{11}]$ compounds of Al. $[T_{11}, T_{23}, S_{14}, S_{15}, T_{27}, S_{15}, T_{32}, S_{16}]$ carbon compounds. $[T_{22}, S_{11}, T_{61}, T_{61}, T_{27}, S_{11}, S_{18}, T_{41}, S_{18}]$ hypothetical compound.

Sample 4: Topic - Isolation of elements from natural sources

Teacher - PAK Observer - SBM

Date: 28-1-1982 Class - IX B

$[T_{11}, T_{22}, S_{11}, T_{22}, S_{11}, T_{22}, S_{11}, T_{13}, S_{14}, S_{23}, S_{14}, T_{15}, S_{27}, T_{11}, S_{16}, S_{27}, S_{16}, T_{18}, S_{18}]$ occurance of elements in nature. $[T_{13}, S_{14}, S_{14}, T_{27}, S_{14}, T_{27}, S_{11}, S_{11}, S_{14}, T_{41}, S_{14}, T_{41}, S_{15}, S_{15}, T_{11}, S_{16}]$ separation of elements from mixtures. $[T_{13}, T_{11}, T_{23}, S_{11}, T_{11}, T_{23}, S_{14}, S_{14}, S_{27}, T_{15}, S_{15}, T_{16}, S_{27}, T_{11}, S_{27}, T_{28}, S_{11}, T_{11}, T_{11}, S_{11}]$ isolation of elements from compounds. $[T_{11}, T_{22}, S_{18}, S_{18}, S_{19}, T_{19}, S_{19}]$ general methods of separation.

Sample 5: Topic - Factors affecting rate of a reaction
Teacher - PAK   Observer - SBM
Date: 11-2-1982.   Class - IX B

[T_{11}, T_{61}, T_{62}, S_{11}, T_{22}, S_{13}, S_{13}, T_{11}, S_{14}, T_{27}, S_{15}, S_{15}, S_{14}, S_{15}, S_{14}, T_{65}, S_{14}, T_{65}, T_{27}, S_{15}, S_{16}, S_{16}, T_{23}, S_{14}, S_{14}, T_{65}, S_{17}, S_{17}, T_{19}] nature of substance as a factor. [T_{63}, S_{14}, S_{14}, S_{17}, T_{27}, S_{14}, T_{23}, S_{14}, T_{62}, S_{14}, T_{52}, S_{65}, S_{65}, T_{52}, S_{65}, S_{66}, S_{66}] physical condition of reactant as a factor. [T_{63}, S_{14}, S_{15}, S_{16}, T_{15}, T_{23}, S_{14}, T_{27}, S_{14}, S_{15}, S_{16}, S_{18}, T_{19}] gaseous reactions. [T_{22}, S_{11}, T_{23}, S_{14}, T_{23}, S_{14} T_{22}, S_{14}, T_{22}, S_{11}, T_{19}] rate of a reaction.

Sample 6: Topic - Chemical equilibrium
Teacher - PAK   Observer - SBM
Date: 25-2-1982.   Class - IX A

[T_{11}, T_{23}, S_{14}, S_{14}, T_{27}, S_{15}, T_{22}, T_{23}, T_{22}, S_{11}, S_{14}, S_{11}, T_{11}, S_{27}, T_{31}, S_{14}, T_{11}] rate of forward reaction. [T_{11}, T_{22}, T_{23}, S_{11}, T_{23}, S_{14}, S_{14}, T_{27}, S_{15}, T_{33}, S_{14}, S_{15}, S_{27}, S_{15}, T_{16} S_{11}, T_{23}, S_{14}, T_{61}, T_{11}] rate of backward reaction. [T_{22}, S_{11}, T_{23}, S_{14}, S_{15}, T_{13}, S_{17}, S_{14}, S_{15}, T_{18}, T_{11}, T_{22}, S_{11}, T_{23}, S_{14}, T_{15}, S_{16}, T_{16}, T_{11}, T_{18}, T_{11}, T_{18}, T_{19}] forward and backward reactions occuring simultaneously. [T_{22}, T_{23}, S_{11}, T_{23}, S_{14}, S_{15} S_{16}, T_{18}, T_{11}] chemical equilibrium.

Sample 7: Topic - Manufacture of Nitrogen.

Teacher: ATS — Observer - SBM

Date: 28-10-1982 — Class - IX A

$[T_{11}, T_{22}, S_{11}, T_{11}, T_{22}, S_{11}, T_{11}, T_{61}, T_{11}]$ liquifaction of air. $[T_{11}, T_{22}, S_{11}, T_{11}, T_{11}, T_{61}, T_{11}]$ separation of nitrogen. $[T_{31}, T_{11}, S_{62}]$ answers to exercise questions.

Sample 8: Topic - allotropic forms of Phosphorous.

Teacher - ATS — Observer - SBM

Date: 25-11-1982 — Class - IX B

$[T_{11}, T_{22}, S_{11}, T_{11}, T_{22}, S_{11}, T_{11}, T_{22}, S_{11}]$ occurance of Phosphorous. $[T_{22}, S_{11}, T_{22}, S_{11}, T_{22}, S_{11}, T_{11}]$ allotropic forms of Phosphorous. $[T_{31}, T_{11}, S_{62}]$ notes on allotropic forms.

Sample 9: Topic - Properties of carbon.

Teacher - ATS — Observer - SBM

Date: 30-12-1982. — Class - IX A

$[T_{11}, T_{61}, T_{11}, T_{61}, T_{11}]$ oxidation properties. $[T_{11}, T_{61}, T_{11}, T_{61}, T_{11}, T_{22}, S_{11}, T_{11}, T_{61}, T_{11}]$ reducing properties. $[T_{31}, T_{11}, S_{62}]$ notes on properties of carbon.

Sample 10: Topic - Petroleum and petroleum products.

Teacher - ATS — Observer - SBM

Date: 20-1-1983. — Class - IX B

$[T_{11}, T_{22}, T_{23}, S_{14}, T_{11}, T_{22}, S_{11}, T_{23}, S_{14}, T_{11}]$ refining of petroleum. $[T_{11}, T_{22}, S_{11}, T_{23}, S_{14}, T_{22}, S_{11}, T_{11}, T_{23}, S_{14}, T_{11}]$ petroleum products.

Sample 11: Topic - Exothermic and Endothermic reactions.
Teacher - ATS
Date: 10-2-1983
Observer - SBM
Class IX B

[T_{23}, S_{14}, S_{14}, S_{14}, > T_{11}, T_{61}, T_{11}, T_{61}, T_{11}] exothermic reactions. [T_{11}, T_{61}, T_{11}, T_{22}, T_{22}, S_{11}, T_{11}, T_{61}, T_{22}, T_{11}, T_{61}, T_{11}] endothermic reactions. [T_{31}, T_{11}, S_{62}] notes on exo and endothermic reactions.

Sample 12: Topic - Factors affecting rate of chemical reactions
Teacher - ATS
Date: 17-2-1983
Observer - SBM
Class - IX A

[T_{11}, T_{22}, T_{11}, T_{61}, T_{11}, T_{22}, S_{11}, T_{11}] chemical affinity as a factor. [T_{11}, T_{22}, T_{11}, T_{61}, T_{11}] physical state as another factor. [T_{11}, T_{22}, T_{11}, T_{61}, T_{11}, T_{22}, T_{11}, T_{22}, S_{11}, T_{11}, T_{61}, T_{11}] concentration of reactants.